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A COMMUNITY PROFILE

Fish and Wildlife Service
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THE ECOLOGY OF LAKE ST. CLAIR WETLANDS: A COMMUNITY PROFILE

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PREFACE

This report on Lake St. Clair wetlands is one of a series of community profiles that deal with marine and freshwater habitats of ecological importance. The delta marshes, estuaries, lagoons, and channel wetlands which fringe the Michigan and Ontario shores of Lake St. Clair, and the St. Clair and Detroit rivers, are among the most productive areas in the Great Lakes. Because they occur in the proximity of a densely populated, heavily industrialized, and intensely farmed region, the marshes have suffered losses in both area and quality. However, the remaining marshes are vital habitats for migratory waterfowl, furbearers, and fish, and perform many important hydrological and ecological functions. The St. Clair Delta is unique in the Great Lakes and fosters some of the finest coastal wetlands in the region.

The biological resources of Lake St. Clair have attracted man since prehistoric time. Not only were fish and wildlife consumed but the wetland plants were used for crafts, cures, and kitchen utensils by the early Indian settlers. Archaeological sites and early explorers of the region have recorded the close interaction of early man and the coastal environment. Lake St. Clair was "discovered" by Europeans on Saint Claire's Day, August 12, 1679, and was named in honor of the saint. Early fur traders were consistently overwhelmed by the bountiful fish and wildlife stocks of the lake and often remarked in their journals about the tranquil beauty of the marshes' flora. A colorful episode of the region was linked to the prohibition era. During this time, local residents claim that the St. Clair Flats, or delta, was a hub of activity for the importation of illegal, but excellent quality, whiskey from Canada to the United States. Today, Lake St. Clair is one of the most intensively utilized lakes in North America with its international wetlands continuing to be significant contributors to recreational activities throughout the year. Without these wetlands, the value of the lake would be greatly diminished.

Lake St. Clair is noted for its storms and rapid water level changes. The moderate energy produced by these storms limits the existence of coastal wetlands to places where some type of natural or artificial protection is available. Correspondingly, the coastal marshes of Lake St. Clair fall into four categories: 1) delta wetlands, 2) coastal lagoons behind protective barrier beaches, 3) estuarine tributary mouths, and 4) managed marshes protected by earthen and rip-rap dikes. According to Cowardin et al. (1979) these wetlands would include elements of riverine, lacustrine, and palustrine systems of the recently developed National Wetland Classification.

The Glossary of Geology (Bates and Jackson 1980) defines "freshwater estuaries" for the Great Lakes as, "the lower reach of a tributary to the lake that has a drowned river mouth, shows a zone of transition from stream water to lake water, and is influenced by changes in lake level as a result of seiches or wind tides." Brant and Herdendorf (1972) were among the first investigators to describe the characteristics of Great Lakes estuaries. Such estuaries are important wetland habitats in western Lake Erie. The definition given above provides an adequate physical decription for the purposes of this report.

The information in this report is intended to provide a basic understanding of the ecological relationships within the

Lake St. Clair wetlands and the impact of natural and man-induced disturbances on the coastal marsh community. References are provided for those seeking more detailed treatment of specific aspects of the coastal marsh ecology. An appendix is included which lists the dimensions and ownership of the major marshes, and the important biological species of algae, macrophytes, invertebrates, fish, amphibians, reptiles, birds, and mammals occurring in the coastal marshes.

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CONVERSION TABLE

FOR METRIC (SI) UNITS TO U.S. CUSTOMARY UNITS OF MEASUREMENT

Metric (SI) units of measurement used in this report can be converted to U.S. customary units as follows:

Multiply	by	To obtain
Linear measurements:		
millimetres (mm)	0.039	inches (in)
centimetres (cm)	0.394	inches (in)
metres (m)	3.281	feet (ft)
kilometres (km)	0.621	miles (mi)
Area measurements:		
square metres (m^2)	10.764	square feet (ft^2)
hectares (ha)	2.471	acres
square kilometres (km^2)	0.386	square miles (mi^2)
Volume measurements:		
cubic metres (m^3)	35.318	cubic feet (ft^3)
cubic metres (m^3)	1.308	cubic yards (yd^3)
cubic kilometres (km^3)	0.240	cubic miles (mi^3)
Mass measurements:		
grams (g)	0.035	ounces (oz)
kilograms (kg)	2.205	pounds (lb)
metric tons (m ton)	1.102	U.S. tons (ton)
Rate measurements:		
centimetres per second (cm/sec)	0.394	inches per second (in/sec)
metres per second (m/sec)	3.281	feet per second (ft/sec)
metres per second (m/sec)	1.943	nautical miles per hour (knot)
cubic metres per second (m^3/sec)	35.318	cubic feet per second (cfs)
metres per hour (m/hr)	3.281	feet per second (ft/sec)
kilometres per hour (km/hr)	0.621	miles per hour (mph)
Temperature measurements:		
degrees Celsius (°C)	9/5°C + 32	degrees Fahrenheit (°F)

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CHAPTER 1. INTRODUCTION

1.1 COASTAL WETLANDS OF THE GREAT LAKES

In recent years there has been an increasing awareness of the resource value of our coastal wetlands and the urgent need to protect and conserve these ecosystems. The wetlands of the Laurentian Great Lakes have been greatly altered by natural processes and cultural practices. The impacts to coastal wetlands in the Great Lakes region has become a subject of particular concern for the emerging coastal management programs in the eight states and the one Canadian province bordering the lakes (Figure 1).

Traditionally, wetland conservation efforts along the Great Lakes have been aimed at protecting waterfowl breeding, or to a lesser degree, fish spawning and nursery habitat. More recent efforts toward preservation are based on the knowledge that wetlands provide additional benefits, including flood control, shore erosion protection, water management, control of nutrient cycles, accumulation of sediment, and supply of detritus for the aquatic food web. Although the intrinsic value of Great Lakes wetland areas are being more fully recognized, no comprehensive studies have been undertaken to characterize the ecological relationships within them. The U.S. Fish and Wildlife Service (Herdendorf et al. 1981a,b,c) inventoried the existing literature of physical, biological, and cultural aspects of the coastal wetlands associated with each of the Great Lakes. Their study pointed out many gaps in our knowledge of the resources found in Great Lakes wetlands, particularly site-specific information on marshes. This report is intended as a contribution toward filling these voids by presenting a profile of the wetland community, a portion of the Great Lakes - the Lake St. Clair-St. Clair River system.

For the purposes of this report, wetlands are defined as areas which are periodically or permanently inundated with water and which are typically characterized by vegetation that requires saturated soil for growth and reproduction. This definition includes areas that are commonly referred to as bogs, fens, marshes, sloughs, swamps, and wet meadows. The coastal wetlands of the Great Lakes are further defined as all wetlands located within 1 km of the lake shore or, if farther from the shore, those directly influenced by water level change of the lakes or their connecting waterways.

Great Lakes coastal wetlands are highly productive, diverse communities which interface between terrestrial and aquatic environments. The most obvious and unique feature of these wetlands is their characteristic vegetation, which provides a diverse community structure offering cover and food for the animal components of the system. Because of the ability of this vegetation to slow the flow rate of water passing through, wetlands are valuable for erosion control, trapping sediments before they reach the open lake, and attenuating the force of waves to lessen their destructive power. The same vegetation provides a natural pollution abatement mechanism by serving as a filter for coastal tributaries through the reduction of the quantity of nutrients and toxic pollutants being washed into the Great Lakes.

Coastal wetlands are highly valued as recreational sites for activities such as hunting, trapping, fishing, boating access to larger bodies of water, birdwatching,

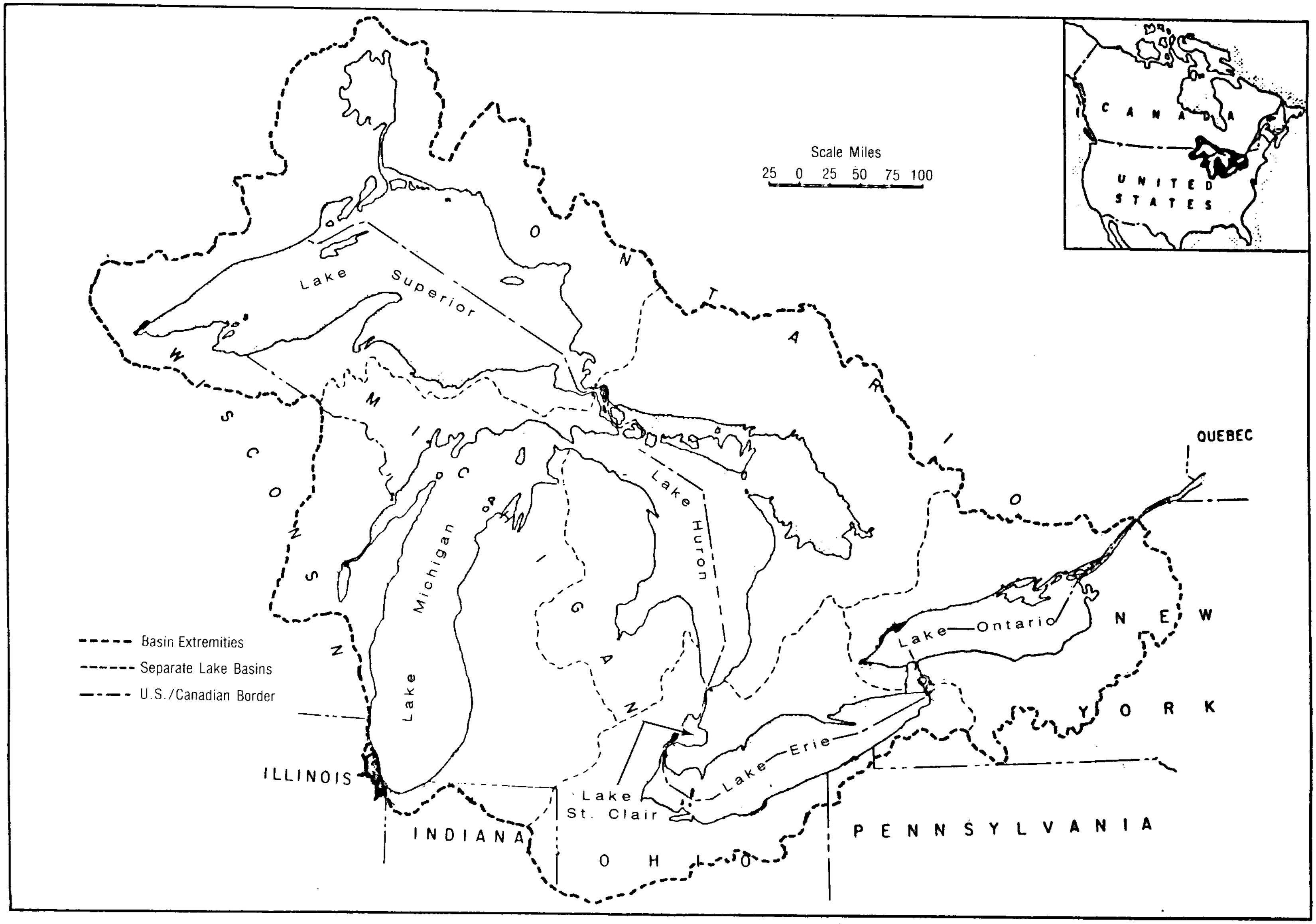

Figure 1. Map of the Great Lakes drainage basin.

and general aesthetic enjoyment. The combination of recreational desirability, agricultural and residential potential, and the proximity of coastal wetlands to larger bodies of water have contributed to their status as endangered environments. Their unique properties are susceptible to numerous natural and human-caused factors that are now causing coastal wetlands to disappear at an alarming rate.

The Laurentian Great Lakes system within the United States (Figure 1) extends from Duluth, Minnesota, at the western end of Lake Superior, to Massena, New York on the St. Lawrence River. It possesses a shoreline length of over 6,000 km and a water surface area of 158,000 km^2. Herdendorf et al. (1981a) enumerated a total of 1,370 coastal wetlands for the Great Lakes and their connecting channels, for a combined wetland area of 1,209 km^2 (Table 1). The greatest number and area of coastal wetlands ring Lake Michigan, the only Great Lake entirely within the United States. Lake Superior has the second highest number of wetlands, but they are relatively small in size. On the average, the largest wetlands are found along Lake Huron and its discharge channel (the St. Clair River); for example, the emergent wetlands of the St. Clair Delta alone cover 36 km^2. The highly industrialized Lake Erie shore has the smallest number and area of wetlands while Lake Ontario has the smallest average size of wetlands, largely due to isolated marshes in the Thousand Islands area of the St. Lawrence River. The presence or absence of coastal wetlands is largely

Table 1. Comparison of emergent coastal wetlands for the U.S. Laurentian Great Lakes.[a]

Lake	Shore length (km)	Number of wetlands	Total area of wetlands (km^2)	Mean area of wetlands (km^2)	Percent of total area (%)
Lake Superior and St. Marys River	1598	348	267	0.77	22.1
Lake Michigan and Str. of Mackinac	2179	417	490	1.18	40.5
Lake Huron	832	177	249	1.41	20.6
St. Clair River, Lake St. Clair, and Detroit River	256	20	36	1.80	3.0
Lake Erie and Niagara River	666	96	83	0.86	6.9
Lake Ontario and St. Lawrence River	598	312	84	0.27	6.9
TOTAL/MEAN	6129	1370	1209	0.88	100.0

[a]Data source: Herdendorf et al. (1981a).

dictated by the geomorphology of a given shoreline and the recent history of water level fluctuations. Each lake has a particular set of geomorphic features which exert control on the development of coastal wetlands.

1.2 COMPARISON OF COASTAL AND INLAND MARSHES

The coastal wetlands of the Great Lakes differ in several ways from inland wetlands. The coastal wetlands are subject to temporary short-term water level changes. Lake St. Clair wetlands are subject to inundation and dewatering by seiches. Long-term cyclic water level changes, related to water budgets of the lake basins, also affect the coastal wetlands. Such fluctuations, occurring over a period of approximately seven to 10 years, may cause vegetation dieback, erosion of the wetlands, or lateral displacements of the vegetative zones of wetlands. Many coastal wetlands, such as those along western Lake Erie, are exposed to relatively high wave energy.

Coastal wetlands along the Great Lakes do not appear to exhibit the aging process associated with inland freshwater wetlands. Because of the fluctuating water levels of the Great Lakes, constant rejuvenation of wetland communities occurs. As a consequence, diagrams in textbooks illustrating the gradual senescence of freshwater wetlands are more applicable to inland wetlands of the glaciated Midwest than to the Great Lakes coastal wetlands. Many inland freshwater wetlands undergo senescence and conversion to terrestrial environments as a result of inorganic and organic deposition (e.g., formation of peat deposits).

Coastal wetlands often display a diversity of landforms not normally encountered in other wetland environments. Owing to changes in the water levels of the Great Lakes since the retreat of the Pleistocene ice sheets, landforms such as coastal barriers, deltas, and natural levees have been deposited. These geomorphological features have influenced the formation of coastal wetlands. The continuing fluctuation of water levels in the Great Lakes is also an important variable in determining many of the distinguishing characteristics and the diversity of Lake St. Clair coastal wetlands, as well as those of the landforms the wetlands occupy.

Coastal wetlands exhibit topographical profiles which are more gentle than what is generally observed in inland wetlands. Many inland wetlands are formed in confined glacial features such as kettle lakes, which exhibit abrupt slopes on their perimeters. Because of the low angle slope conditions, vegetation zonation is more distinct and better displayed in coastal wetlands. As described in this report, the St. Clair Delta is colonized by several broad submersed and emersed wetland zones. Inland wetlands, however, are more confined and do not display the extensive zonation observed in the coastal zone.

Water levels in coastal wetlands are determined by climatic factors over several years. Generally, annual higher water levels in the Great Lakes occur in late summer and lower levels occur in January. Water level changes in inland wetlands respond to immediate or short term runoff conditions. High water most often occurs in the spring when runoff is highest; low water levels occur in early fall.

Furthermore, the contribution of groundwater flow is more significant to inland wetlands. During the dry summer months with high evapo-transpiration rates, the survival of such wetlands may depend on groundwater inflow. Great Lakes' controlled wetlands, however, shift landward or lakeward depending upon water level conditions over several years. Clearly, the relationship between groundwater and wetlands is intimate in inland areas, but this relationship in the coastal zone is less significant.

In the Great Lakes, with few exceptions, the substrate is composed of mineral sediments. Because of the flushing action of seiches and periodic water level changes, organic deposits are not common. Conversely, the hydrologic connectivity of inland wetlands is poorer. Fine mineral soils, with high organic content in the inland marshes, contribute

to their gradual senescence and account for more acid-tolerant vegetation than that found in the coastal wetlands. Peat is not typically found along the coast of Lake St. Clair.

1.3 FUNCTION AND VALUE OF COASTAL WETLANDS

Coastal wetlands in the Great Lakes are multi-functional because these environments are part of both the uplands and the open-water ecosystems. It is the interface with the Great Lakes that multiplies the wetland functions and contributes to the "open system" dynamics. Streams and coastal waterways enhance the ecosystem connectivity, while obstacles such as earthen berms and dikes result in coastal wetland fragmentation and loss of function. Functional loss then, can result from both bank-derived and lake-derived forces. An awareness of the effect of long-term lake level changes on the function of the coastal wetlands is beginning to emerge, and the concept of pulse stability is being ascribed to these environments.

During the past decade, considerable research was carried out regarding the function and value of wetlands. Important general sources include Tiner (1984), Greeson et al. (1979), and Messman et al. (1977). In reference to the Great Lakes, significant contributions were made by Herdendorf et al. (1981a,b,c), Raphael and Jaworski (1979), Jaworski (1981), Jaworski and Raphael (1978), and Tilton et al. (1978). According to the U. S. Fish and Wildlife Service Classification (Cowardin et al. 1979), most Great Lakes wetlands would be classified as lacustrine or palustrine.

Wetland functions are those processes occurring in wetlands which are associated with the functioning of the ecosystem or with the hydrosystem. Examples of such functions are primary production and water storage. In contrast, wetland values are those wetland products or services which satisfy a human need. Commonly, economic values are employed to such wetland commodities and services. As a result, one may refer to the dollar value of a waterfowl hunting day, as well as to concepts such as marginality (or scarcity value) and opportunity costs. Nevertheless, not all wetland functions (e.g., flood water storage) are vendable in the marketplace.

In response to Section 404 and other permitting authority, the U.S. Army Corps of Engineers (Reppert and Sigleo 1979) developed the following list of wetland functions and services:

1. Natural biological functions
   a. net primary productivity
   b. food chain (web) support

2. Habitat for aquatic and wetland species

3. Aquatic study areas, sanctuaries and refuges

4. Hydrologic support functions;
   a. shoreline protection from wave attack
   b. storage of storm and flood waters
   c. water purification through natural filtration, sediment trapping, and nutrient cycling uptake
   d. groundwater recharge

5. Cultural or auxiliary values including consumptive and nonconsumptive recreation as well as aesthetic value.

Except for item 5, these wetland benefits tend to accrue to the public, and are not generally vendable by a private landowner.

Quantitative economic value data for Great Lakes wetlands are available. A study by Jaworski and Raphael (1978) basically addressed the cultural values using a gross annual economic return methodology, whereas Tilton et al. (1978) focused on ecosystem replacement values in regard to fish production, waterfowl feeding/breeding, nutrient removal and control, and water supply. By combining the results of these two studies and updating the data to 1980, a more complete account of the economic value of Michigan's coastal wetlands can be presented (Table 2).

Although methodologies are mixed, Table 2 is useful in establishing economic values within an order of magnitude and in priority. Notice that nutrient control, sport fishing, and fish production are clearly of more value than the traditional uses, i.e., waterfowl hunting, trapping, water supply, and commercial fishing. Conversely, these data are presented as average economic values, even though not all wetlands are alike. Moreover, the methodologies did not consider surplus value, as would be assessed by the willingness to pay technique.

Table 2. Economic value of Michigan's coastal wetlands, 1980.[a]

Economic sector	Annual value (per hectare)	Annual value (per acre)
Runoff Nutrient Control	$1,680	$679
Sport Fishing	1,054	426
Fish Production	1,040	420
Waterfowl Breeding/Feeding	720	291
Nonconsumptive Recreation	366	148
Waterfowl Hunting	103	42
Trapping of Furbearers	74	30
Water Supply	16	6
Commercial Fishing	13	5

[a]Data source: Jaworski (1981).

Wetland functions and values vary from wetland to wetland (i.e., spatially) as well as from year to year (i.e., temporally), particularly as a result of precipitation and hydrologic changes. Jaworski et al. (1979), studied the effect of water level fluctuations on seven wetland complexes in the Great Lakes region, including Dickinson Island of the St. Clair Delta. As illustrated in Table 3, wildlife use and wetland functions change as water levels fluctuate. As discussed in Section 2.3, low water levels occurred in 1964-65 whereas record high levels took place during the 1972 to 1974 interim.

During low water levels, the emergent communities of cattails and sedges are very dense and the water table lies beneath the mean level of the marsh surface. It is at such low water conditions that waterfowl management calls for diking and flooding of these emergent communities. Conversely, during high water periods the hydrologic circulation is facilitated and lake water can enter the wetland via inlets, canals, and breaches in barrier beaches. Excessive high water is associated with plant community retrogression as well as erosion of the nearshore vegetation and beaches. Therefore, the function and value of a coastal wetland is most dynamic, and short-term studies of wetland values should receive careful interpretation.

In summary, a multi-functioning wetland tends to have a higher value than those with fewer functions. Conversely, coastal wetlands which are isolated by barriers or degraded by factors such as land drainage, exhibit fewer functions and have lower values. Moreover, wetlands vary in value from place to place and temporally as well, especially in response to lake level changes. In addition, continual wetland acreage loss results in a marginality value of those extant wetlands. The Lake St. Clair wetlands have exceptional value due to their ecosystem relationship with the lake and connecting channels. The decline of western Lake Erie marshes has also enhanced the relative value of the Lake St. Clair wetlands.

In recognition of the special environmental value of wetlands, Federal and State legislation has recently been enacted to protect these areas. In concert with the National Wetland Inventory program, each State in the United States has begun the process of inventorying and mapping their wetland resources. Wetlands whose hydrologic regime has been altered or destroyed may be mitigated.

1.4 LAKE ST. CLAIR WETLANDS

Distribution

The outlet of Lake Huron is through the St. Clair River, Lake St. Clair, and

the Detroit River to Lake Erie (Figure 2), a distance of 139 km with a fall of 2.4 m. Lake St. Clair is an expansive, shallow basin having a distinctive heart shape. Although not one of the world's largest lakes, it does rank 122 on the basis of surface area (Herdendorf 1982). The lake has a surface area of 1,110 km^2 and a drainage basin of 16,900 km^2. A 29 km-long navigation channel, dredged to a depth of 8.2 m below low water datum (LWD), extends from the mouth of the St. Clair River to the head of the Detroit River. Lake St. Clair has a shoreline length of approximately 272 km. The shore of the St. Clair River, including main distributary channels, adds 192 km and the head of the Detroit River, plus Belle Isle, add 32 km of shoreline to the study area. Of this total shoreline length of 496 km, approximately 188 km or 38% can be classified as coastal wetlands (Table 4 and Appendix A).

The delta is the most characteristic feature of the St. Clair River-Lake St.

Table 3. Wildlife use and other functions of coastal wetlands at low and high water levels.[a]

```
                                          Water level[b]
Use/Functions of wetlands           Low Water          High Water

Wildlife use

    Blue-winged teal (breeding)     - - - ----------
    Red-winged blackbird            -------------------- - - -
    Mallard (breeding)                - - ---------------------- - - -
    Sedge wren                      ---------- - -
    Muskrat                         - - - -------------------- - - -
    Black tern                                          - - ----------
    Yellowheaded blackbird                              - - ----------
    Great blue heron                           - - - - ----------------
    Belted kingfisher                          - - - - ----------------
    Crayfish                                   - - - - ----------------
    Frogs and turtles                              - - ----------------
    Fish spawning (pikes)                            - ----------------
    Forage fish                                        - --------------
    Dabbling ducks (feeding)        -- - - ------------------- - - - -
    Diving ducks (feeding)                           - - -------------

Other Functions

    Peat accumulation               --------- - - - -
    Sediment trapping                 --------- - - - -
    Hemi-marsh                                    - - - ---------------
    Water circulation                             - - - ---------------
    Dominance of land drainage      --------- - -
    Dominance of lake water masses              - - - -----------------
    Turbidity levels                              - - - ---------------
    Export of detritus                          - - - -----------------
    Re-suspension of in situ clay                   - ---------------
```

[a]Data source: Jaworski et al. (1979).

[b]Use or function relative to water level indicated by line.

Clair system. The St. Clair Flats is a massive deposit formed by a series of active and inactive distributaries at the mouth of the river. This is the largest delta in the Great Lakes system. The Michigan portion of the delta has been urbanized to some extent, but the Ontario portion has been set aside as an Indian reservation. The Ontario side of the delta, along with State wildlife areas on the Michigan side, represent the finest coastal wetlands in the Lake St. Clair system.

The shoreline of the St. Clair River has been intensively developed for residential, commercial, industrial, and recreational use. The only extensive natural areas are on the delta wetlands (St. Clair Flats), formed where the river enters Lake St. Clair. The vegetation of the St. Clair Delta occurs in broad arcuate zones which extend from the apex near Algonac, south into Lake St. Clair. The zones show a progression from hardwood forests near Algonac to cattail and bulrush marshes at the lake.

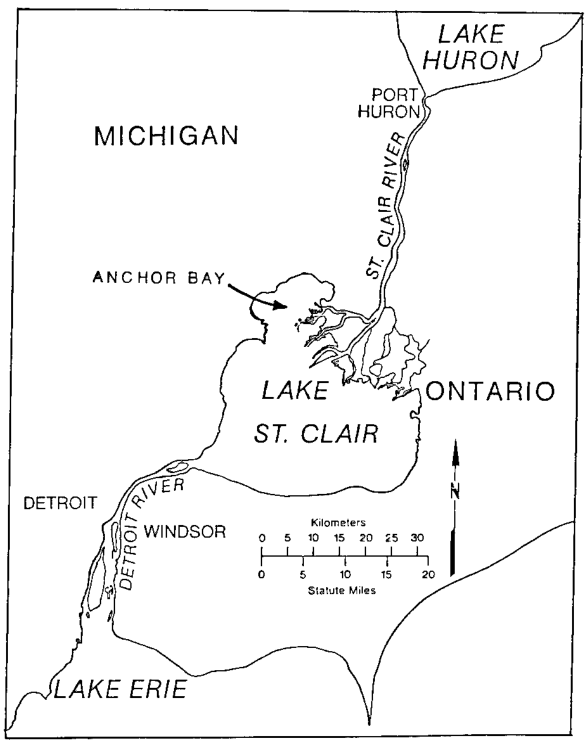

Figure 2. Map of St. Clair River-Lake St. Clair-Detroit River ecosystem.

Lake St. Clair has a shallow, expansive basin with low marshy shores. Other than the delta, the best coastal marshes are found on the east shore of the lake between Mitchell Bay and the mouth of the Thames River (Ontario) and in Anchor Bay between the delta and the mouth of the Clinton River (Michigan). The only other notable wetlands are submerged beds of aquatic plants in the vicinity of Peach Island and Belle Isle at the head of the Detroit River.

Lake St. Clair, the smallest lake in the Laurentian Great Lakes system, has a mean depth of only 3.0 m, a maximum natural depth of 6.4 m, and a volume of

Table 4. Estimated dimensions of Lake St. Clair and St. Clair River emergent and submergent wetlands.[a]

Jurisdiction	Coastal length of wetlands (km)	Area of wetlands (km^2)
MICHIGAN		
Wayne County	4.0	0.7
Macomb County	6.6	11.2
St. Clair County	75.2	140.7
Michigan Total	85.8	152.6
ONTARIO		
Essex County	11.5	6.8
Kent County	26.5	62.8
Lambton County	64.4	161.7
Ontario Total	102.4	231.3
TOTAL	188.2	383.9

[a]Data sources: United States Geological Survey, Dept. Interior, 7.5-minute Quadrangle Maps (1:24,000 scale); Canada Department of Energy, Mines and Resources, 7.5-minute Quadrangle Maps (1:25,000 scale); Direct field and aircraft observations, 1983 and 1984.

4.0 km^3. Its deepest waters are found along a dredged navigation channel which extends from the mouth of the St. Clair River to the head of the Detroit River. Approximately 98% of the water flowing into Lake St. Clair enters through the St. Clair Delta. The Detroit River, the only outlet, drains Lake St. Clair at a rate of 5,044 m^3/sec. This yields a retention time for the lake basin of only 9.2 days.

The St. Clair River is one of the four major connecting channels on the Great Lakes, flowing between Lake Huron and Lake St. Clair. The two principal cities on the river are Port Huron, Michigan, and Sarnia, Ontario, both at the head of the river at Lake Huron. The St. Clair River has two characteristic sections, the upper channel, and the lower, or delta, portion. The upper channel runs from Lake Huron to the head of Chenal Ecarte, a distance of 43 km. There are two islands in the upper portion of the river, Stag Island and Fawn Island. At Chenal Ecarte, the river begins to branch out into a number of distributaries, forming a vast pattern of islands, marshes, and waterways that are known as the St. Clair Flats.

The St. Clair River receives most of its flow from Lake Huron. Principal tributaries in Michigan are the Belle, Black, and Pine Rivers. Water quality throughout the St. Clair River is generally excellent. Some degradation occurs in localized areas where tributaries join the river. The width of the St. Clair River ranges from about 250 to 750 m, and the maximum depth ranges between 11 and 15 m. The river's annual average discharge is about 5,070 m^2/sec. Because the river's main water source is Lake Huron rather than surface runoff, seasonal flow variations are minimal.

Herdendorf et al. (1981c) listed four wetland complexes that are located in the lower portions of the St. Clair River. The Pointe Aux Tremble Wetland (15 hectares), the Pointe Aux Chenes Wetland (7 hectares), and the Russell Island Wetland (5 hectares) are all located in the North Channel of the St. Clair River. The Algonac Wetland (64 hectares) is located 0.3 km from the shoreline of the river. The Cuttle Creek Area Wetland (1.5 hectares) and the Port Huron Area Wetland (1.2 hectares) are both located along the upper portion of the river.

General Description

Although the largest area of wetlands is found in the St. Clair Delta, there are fragments of wetlands around the perimeter of Lake St. Clair. Beginning at the mouth of the Detroit River, small patches of riverine, palustrine, and lacustrine open-water wetlands exist along Belle Isle. Aquatic beds of submersed vascular plants dominate as a park and other developments have resulted in the removal of the upper communities.

Along the southwestern shore of Lake St. Clair, from Grosse Pointe to the Clinton River, the shoreline is intensively developed. Much of the shoreline is protected by seawalls, and piers and marinas are scattered along this stretch. Although the shoreline is classified as lacustrine open-water wetlands, there is little wetland vegetation except for pollution-tolerant submersed aquatics such as coontail and Eurasian water-milfoil growing in the boat channels and slips (see Appendix E for common and scientific names of vascular plants).

Where the Clinton River empties into Lake St. Clair, along the western shore of Lake St. Clair, there are two coastal wetland areas. South of the river, in the Metropolitan Beach area, over 4 hectares of palustrine emergent and palustrine open-water wetlands exist. North of the Metropolitan Parkway highway, i.e., along Black Creek, which is an old tributary of the Clinton River, there are sedge meadow, cattail, and open-water (aquatic bed) communities. Because the connection with Lake St. Clair is poor, the water frequently stagnates resulting in lower fish and benthic invertebrate values. North of the Clinton River, located between Sand Point and Selfridge Air Force Base, is an open wetland. This wetland is largely a palustrine system with submersed aquatic plant communities.

The shoreline of Anchor Bay, situated in northwest Lake St. Clair, is also

largely urbanized. Residential development, marinas, and boat slips are common in the mouths of streams as well as in lakeshore points. Very little undisturbed wetland exists and much of the shoreline is either bulkheaded or piled with rip-rap to reduce erosion associated with the current high water levels. Although the entire shoreline is classified as lacustrine open-water wetlands, only scattered patches of emergent cattails and submersed aquatics exist along the creek mouths and behind bulkheads. Clumps of bulrushes occur along the shoreline, along with strips of wild celery and other wave tolerant submersed aquatics.

The first large area of deltaic wetland occurs along Bouvier Bay, and is locally referred to as St. John's Marsh. Approximately 1,000 hectares in size, this wetland complex is found along both sides of Highway M-29, and extends from Fair Haven to Pearl Beach. Plant communities in this wetland are dominated by palustrine emergents and include sedge meadow, cattails, bulrushes, and floating-leaved and submersed aquatics. Construction of coastal access roads and filling for residential development as well as the building of highway M-29 have fragmented this wetland.

Dickinson Island is the largest natural, undeveloped, and functioning wetland complex along Lake St. Clair. Approximately 1,200 hectares, this wetland has a continuum of environments. To the north, where elevations average 1.5 to 3 m above North Channel, swamp forest and dogwood shrub communities occur. In the middle of this deltaic island, several abandoned river channels bisect vast stretches of sedge meadow and cattail communities. Along the shoreline, the emergent wetlands give way to various open-water aquatic bed-type wetlands.

Another major wetland complex along the American side of the St. Clair Delta is Harsens Island. Only the lower quarter of this deltaic island remains a wetland, consisting largely of hybrid cattail (Typha x glauca) colonies along with the associated floating-leaved and submersed canal and shoreline communities. The center of Harsens Island is part of the St. Clair Flats Wildlife Area and is traditionally planted in corn and other artificial waterfowl foods. Most of Dickinson Island and the lower half of Harsens Island together make up the St. Clair Flats Wildlife Area, which is managed by the Michigan Department of Natural Resources for waterfowl hunting.

With reference to the Ontario side of the St. Clair Delta, that wetland complex includes portions of Bassett Island, Squirrel Island, Walpole Island, and St. Anne Island. Bassett Island consists mostly of cattail marsh with open-water ponds and a thin beach colonized by shrubs and herbaceous plants. Squirrel Island is also largely a natural cattail marsh, but the northern part, where sedge marsh would naturally occur, is diked off and cultivated.

Canada's major wetland complex in the delta focuses on Walpole Island where Goose Lake and Johnston Bay are located. Deciduous woodlands, shrubs, and sedge meadows form the upper part of this island, but much of the natural shrub and meadow zones have been cleared and plowed into row-crop agriculture. A diked and water-level regulated cattail marsh occurs north of Goose Lake. South of Goose Lake the wetlands are dominated by cattails and sedge communities along the distributary channels and shoreline beaches. The wetlands near Johnston Bay are open to Lake St. Clair.

The wetlands on St. Anne Island appear much more managed. Large corn fields on the upper and middle portions of the island extend to the limit of the cattail marsh. At this point, the marshes are diked for the benefit of private waterfowl clubs. Only the shoreline fringe of the wetlands is open to Lake St. Clair.

The last major wetland area along the Ontario side of Lake St. Clair is in the Mitchell Bay area. Because of the proximity of the managed marshes on St. Anne Island and the cultivation by Canadian farmers right up to the lakeshore in Kent and Lambton counties, the wetlands of Mitchell Bay consist mainly of open-water or submerged communities. Moreover, considerable diking and waterfowl nesting improvements have taken place along Mitchell Point.

CHAPTER 2. PHYSICAL ENVIRONMENT

2.1 GEOLOGY

This section contains a description of the geographic location of the study area, including a discussion of topography, morphometry, and coastal geomorphology. Although no bedrock or glacial features are directly related to the distribution of wetlands there are biogeographical associations with more recent landforms such as natural levees, crevasse deposits, interdistributary bays, and other deltaic deposits.

The occurrence and distribution of wetlands is determined, to a significant degree, by a combination of physical factors. In the Great Lakes, coastal wetlands are at the interface of land, water, and atmosphere. These three components of the biosphere are delicately balanced to produce and maintain the biological resource. In this chapter the physical parameters of the Lake St. Clair wetlands are examined.

Wetlands occur in basins or topographical depressions which are wet or flooded for at least several months of the year. The occurrence of the resource is therefore in part determined by water depth, which is in turn determined by the submarine topography, sedimentation, and character of lake level oscillations. Another factor responsible for wetland distribution is wave action in open water bodies and current characteristics in riverine and littoral areas. Many of these factors are in turn directly related to climatic conditions. A simplified diagram illustrating these relationships appears in Figure 3.

The more extensive wetlands of the Great Lakes are located in ancient lake bottoms or in areas of high sedimentation

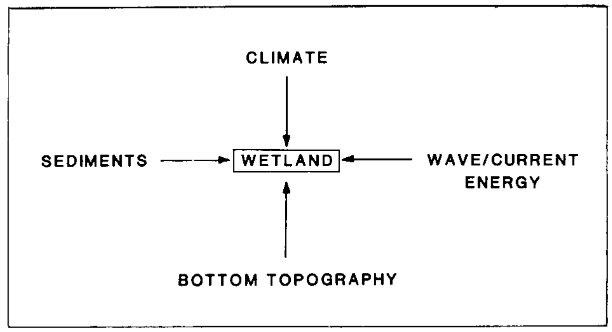

Figure 3. Physical factors influencing the occurrence of coastal wetlands.

rates. In the geological past, water levels in the Great Lakes were higher and proglacial lakes inundated the lower terrain. As the water levels of the lakes dropped, a series of clay lake plains were exposed which were colonized by vast wetlands. Western Lake Erie, including the Maumee River embayment, for example, was an extensive wetland known as the Black Swamp. The margins of Lake St. Clair, especially in Ontario, are composed of a similar deposit.

The rivers flowing into Lake St. Clair deposited sediments along valley floors to create floodplains which were colonized by wetland communities. At the same time deposition in the lake created the St. Clair Delta. Although most of Michigan has a glacial heritage, coastal wetlands are a product of fluvial, deltaic, and lacustrine sedimentation.

The St. Clair Delta has been deposited, in part because of the shallowness of Lake St. Clair. Compared to marine shorelines, ongoing coastal deposition which produces subaerial landforms such as the delta is not common in the Great

Lakes. In fact, no other significant deltas occur in the Great Lakes. The combination of a shallow receiving basin and an abundance of sediments is largely responsible for the deposition of the St. Clair Delta which is colonized by the most extensive wetlands in the coastal Great Lakes.

The progradation or recession of the coastal zone is largely influenced by wave and currents. High energy environments discourage the establishment of palustrine and lacustrine wetlands. Also high wave energies hinder delta deposition and growth. In Lake St. Clair wave and current energy are not excessive. This physical condition has allowed the development of the delta with its diverse wetland habitats. Also the low wave energies have encouraged wetland colonization north of the Thames River along the eastern shoreline of the lake.

The climatic elements including temperature, precipitation, evaporation, and wind velocities and directions exert a control on water levels and wave parameters. These in turn dictate wetland occurrence and types. With changes in water levels the geographical distribution of wetlands shift or "pulse stability" occurs. Also the character of sedimentation is altered to a point where water quality (i.e., turbidity) levels are impacted.

Geomorphic Setting

It has been determined that wetlands in the Great Lakes colonize a diversity of geomorphic settings such as backbarrier flats, alluvial flood plains and deltas. The St. Clair Delta (Figure 4) is made up of a suite of landforms which support a diversity of wetland types. Deltaic deposits in the Great Lakes are rare features, suggesting that fluvial sedimentation is not abundant and/or wave energies are too high thus not permitting delta development to occur. Therefore the St. Clair Delta is a unique Great Lakes'

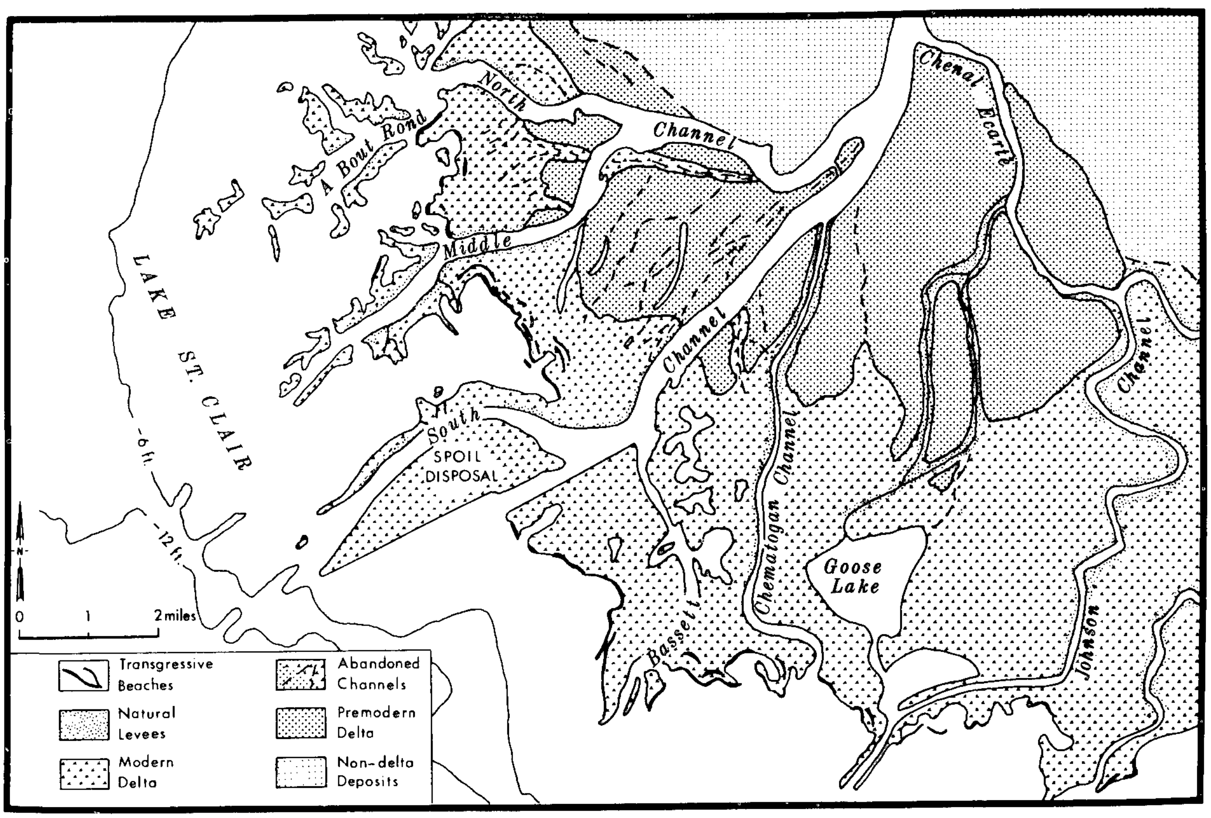

Figure 4. Depositional features and landforms of the St. Clair Delta.

coastal feature supporting abundant and diverse wetland communities not found on other Great Lakes' shorelines.

Since the classical study of Lake Bonneville by Gilbert (1890), deltas in lakes, with only a few exceptions, have been largely ignored by geomorphologists. The major deltas of the world are located on continental shelves and have held the interest of geologists and geographers because of petroleum resources, agricultural production, and waterborne activities. Although lake deltas are smaller, they share most of the processes characteristic of marine deltas. However, a unique aspect of lake deltas is their dynamic response to relatively rapid changes of base level that not only produce special landforms, but distinctive vegetation zonation as well.

The St. Clair Delta is the largest delta in the Great Lakes basin. Despite the delta's recreational significance and commercial importance with regard to navigation, literature on the area has not been abundant. The first significant investigation was done several decades ago by Cole (1903) who determined that the delta was being deposited atop deep water, proglacial lake clays. More recently, Wightman (1961) attempted to establish a late Quaternary chronology for the delta's formation. Detailed investigations by geologists have partially documented the sedimentological composition of the delta's surface, particularly in Muscamoot and Goose bays (Pezzetta 1968, Mandelbaum 1969). During the 1950s, engineering studies by the U.S. Army Corps of Engineers preceded construction of the 8-m deep St. Clair Cutoff Channel through the delta. Although not published, much of these data, in the form of bore records, are on file at the Detroit District Office. Recent environmental studies associated with flooding problems on the shores of Lake St. Clair and dredged spoil disposal site locations have also contributed some useful data for this section of the study (U.S. Army Corps of Engineers 1974).

With the retreat of the Late Wisconsin ice sheet some 13,000 years ago, a series of moraines and till plains were deposited in the Great Lakes basin. The outlets of the Great Lakes were changing or even blocked, causing the lake levels to oscillate several meters. Lake Erie established its present level some 4,000 years ago and Lake Huron shortly thereafter. The St. Clair River and its delta came to existence during these changing lake levels.

Deltaic Landforms

As a lake delta, the St. Clair exhibits several of the landform characteristics of marine deltas, such as active and inactive distributaries, interdistributary bays (Figure 5), and crevasses or wide breaches in the channel banks which lead into interdistributary bays (Figure 6). The St. Clair Delta has a classical bird-foot morphology, as does the Mississippi River Delta. However, significant landform differences are also apparent. Atypical landforms include a premodern surface at the apex of the delta and unusually wide distributary channels.

Figure 5. Little Muscamoot Bay, an interdistributary bay between Middle Channel and South Channel of the St. Clair Delta (August 1984). Note emergent cattails (Typha angustifolia) and solitary pied-billed grebe (Podilymbus podiceps).

Figure 6. Well-developed crevasse deposits adjacent to Middle Channel of St. Clair Delta. These crevasses have been intermittently active for over 100 years. Dickinson Island is to the upper left and Harsens Island is to the lower right.

The active distributaries--North, Middle, and South Channels--average some 500 m in width and 11 m in depth. However, widths of 675 m and depths of 26 m are not uncommon. At the mouths of the distributaries, channel depths decrease abruptly indicating the presence of river mouth bars 2 to 4 m below mean lake level. As a depositional basin, Lake St. Clair is relatively small with a maximum natural depth of 6.4 m and width of 40 km.

North, Middle, and South Channels exhibit shoulder-like features or shoals along both the cutbank and point-bar sides (Figure 7). A similar morphology has been attributed to periodic cut and fill associated with slight base level oscillations (Butzer 1971). Borings obtained from the Corps of Engineers reveal that the distributary channels of the St. Clair Delta are entrenched in lacustrine clays which lie beneath a 3.5 to 5 m veneer of coarser deltaic sediments. On the cutbank side, where flow velocities may be relatively high during high water conditions, an erosional berm usually less than 2.5 m below the water surface slopes gently from the cutbank toward the channel center. These features may be caused by lateral erosion of the fine, sandy deltaic sediments which overlie the lacustrine clays. On the inside bank, especially along Middle Channel, point bar deposits characterized by ridge and swale topography are conspicuous. Here the distributary shoulders probably represent a fill deposit which is colonized by emergent vegetation during low-water periods.

Because the water level fluctuates only 45 to 60 cm seasonally, spring floods are not a normal occurrence within the delta, hence natural levees are scarcely discernable adjacent to modern distributaries. Even though levees are poorly developed, averaging 10 to 45 cm in elevation, flooding and subsequent overbank flow does occur. Overbank flow is associated with breaching of levees in abnormally low areas along a levee. As a

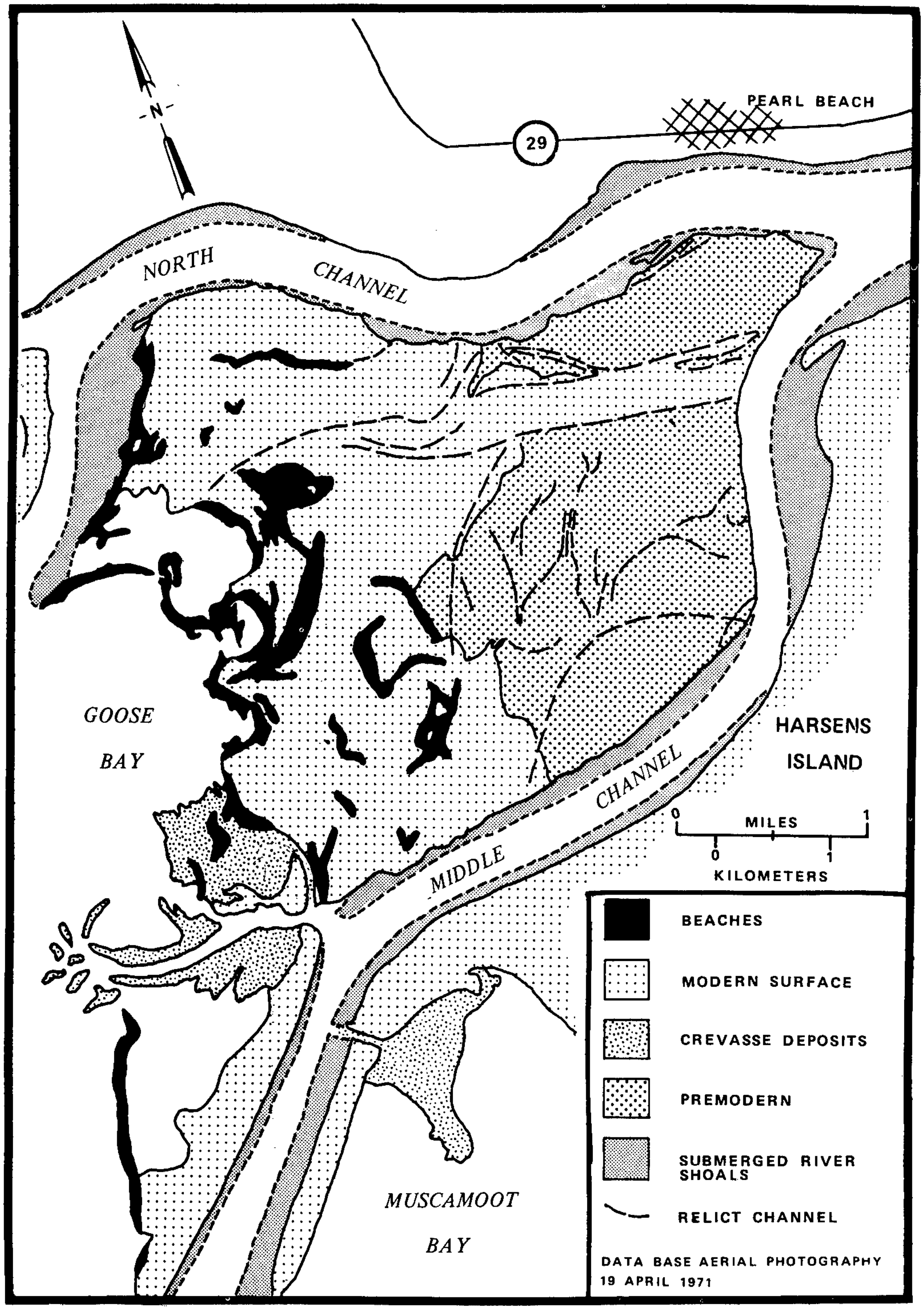

Figure 7. Deltaic landforms of Dickinson Island, Michigan.

levee is breached, crevasse deposits are introduced into the interdistributary bays at right angles to the channels (Figure 7). With continued deposition, the open-water bay will be filled with crevasse deposits and colonized by sedges and emergent aquatics.

Crevasse channels, locally known as "highways" (see Figure 57 in Section 5.1), are operative for several years. Nevertheless, deposition into the bays is not rapid. A comparison of navigation maps reveals that such features may be part of the delta landscape for over a century. Pezzetta (1968) graphically compared the western portion of the delta front between 1903 and 1961. Over the 58-year period crevasse fills were minor. In fact human-made alterations such as dredging and bulkheading dominated the landscape. This suggests that crevasse channels are active intermittently and transport little sediment into the interdistributary bays.

During the winter and early spring when Lake St. Clair is frozen, pack ice accumulates at the mouths of distributaries forming ice jams. Channel flow is then diverted into crevasses and some overbank flow may occur. Because the dominant grain size is sand, little bed load sediment is transported from the deep distributaries into the interdistributary bays. Thus, in the St. Clair Delta the filling of interdistributary bays and delta growth is a slow process.

In contrast, the Mississippi Delta crevasse deposits rapidly convert open interdistributary bays into mud flats which are subsequently colonized with marsh grasses. During flood stage, the crevasse channels are scoured deep enough to be maintained and rapid deposition occurs. In the past 135 years, crevasse deposits have transformed the open interdistributary bays of the modern Mississippi River Delta into a complex of marshy subdeltas (Coleman 1976).

Beaches on the present delta shoreline are poorly developed and appear transgressive in origin. On the Canadian side, where the beaches are somewhat better developed, the berms may reach 1 to 1.5 m in height and are colonized with sumac and small trees. Borings reveal that the principal constituents of these beaches are coarse sand or fine gravel (0.3 mm or -1.5 phi units) separated by layers of sand and organic materials including rafted logs, bulrush stems, and other debris. Coarse sands and fine gravels are not evident, and storm berms seldom exceed 0.7 m in elevation. Characteristic vegetation of these shoreline features are either sedge marsh or a complex community of grasses, thistles, and other nonwoody species.

Within the interdistributary marshes, especially on lower Dickinson and Harsens islands, are arcuate-shaped features resembling beach ridges. Borings through one of these ridges revealed up to 3 m of fine sand (Raphael and Jaworski 1982). The absence of washover deposits and organic sediments indicate that these features may be regressive beaches and represent shorelines as delta accretion took place.

A comparison between the eastern and western portions of the St. Clair Delta illustrates two other distinct differences. On the Canadian side, Chenel Ecarte and Johnson Channel are narrow, shallow distributaries which do not carry a significant portion of the volume of the St. Clair River. Moreover, open interdistributary bays are few and are colonized by marsh vegetation. Delta extension has ceased and maximum delta accretion is now occurring to the west as evidenced by the active digital distributaries of North, Middle, and South Channels, and Chenal A Bout Rond. In the past, Chematogan and Bassett Channels were approximately 500 m wide comparable to the modern distributaries, but have been alluviated and colonized with aquatic plants as abandonment occurred.

In most deltas with large fluvial systems, lateral migration of the delta occurs because of the changes in the course of the river upvalley. The premodern lateral displacements of the Mississippi River Delta originated within the alluvial valley several miles from the Gulf of Mexico's coast. Such a diversion process is evident in some lake deltas as well. Several older deltas of the Omo River, for example, have been identified

and related to the former position of the river within its alluvial valley (Butzer 1971).

The St. Clair Delta, however, has no comparable alluvial valley, and delta migration has occurred from east to west at the shoreline of Lake St. Clair. As the Canadian distributaries degenerated, new distributaries were created on the western side of the delta.

Delta Stratigraphy and Geomorphic History

A series of borings, cores, and exposures indicates that in cross section the St. Clair Delta is a thin and sandy deposit. An east-west cross section reveals that above the shale bedrock, lacustrine clays have been deposited over a thin deposit of glacial till (Figure 8). The coarse deltaic deposits, having a maximum thickness of 7 m rest upon blue lake clays.

The north-south cross section from the apex of the delta into Lake St. Clair illustrates the near-surface stratigraphy (Figure 9). Topographically however, this cross section reveals two distinct levels, a modern and the equally obvious premodern surface. The premodern surface, standing about 1.5 m above Lake St. Clair, consists of coarse, oxidized sand and is confined to the apex of the delta complex. It has been dissected by long, sinuous channels which have been alluviated. Occasionally during high lake levels these channels have been reoccupied, particularly in areas such as Dickinson Island, where human interference has been minimal. Because this higher surface is topographically and sedimentologically distinct, it must be a surface which was deposited during a pre-existing higher lake level. The modern delta with its fine sand sediment (0.25 to 0.125 mm or +2 to 3 phi units) is located at present mean lake level and is represented by the active crevasses and interdistributary marsh deposits.

Based on the chronology of the proglacial Great Lakes, field data, and

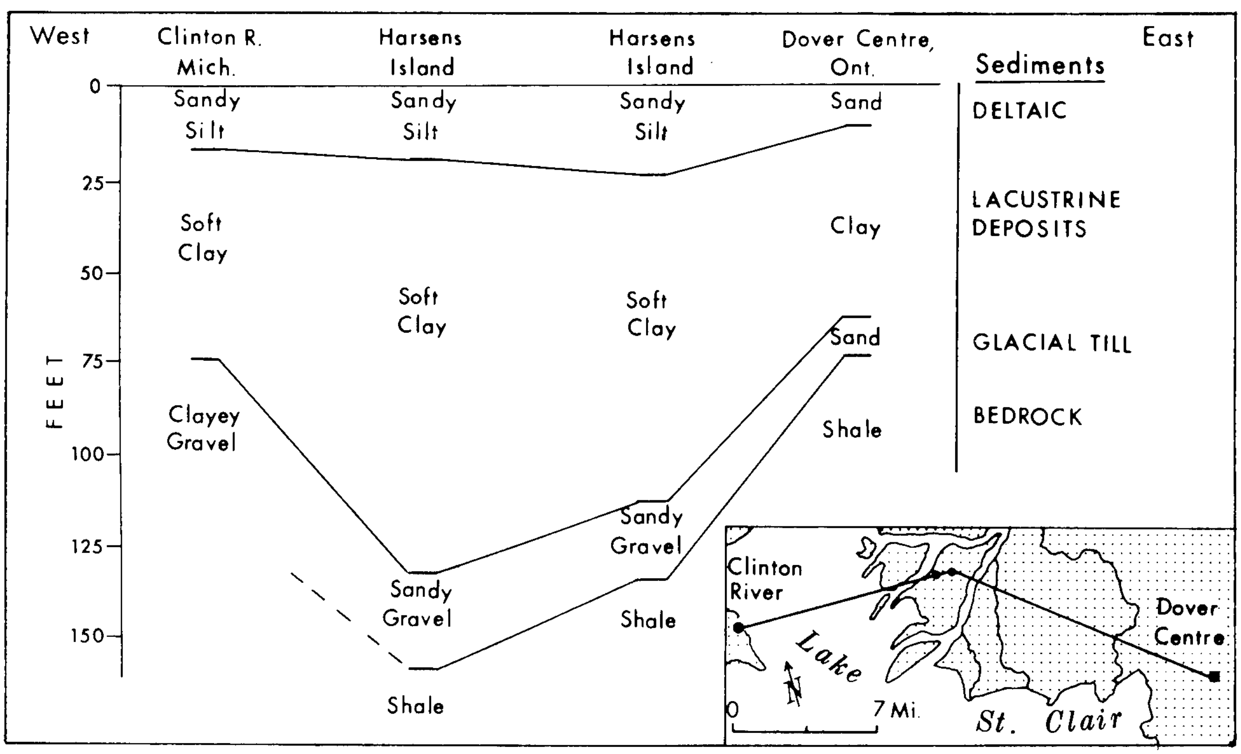

Figure 8. Geologic cross-section of the northern portion of Lake St. Clair showing depth to bedrock, and thickness of glacial, lacustrine, and deltaic deposits.

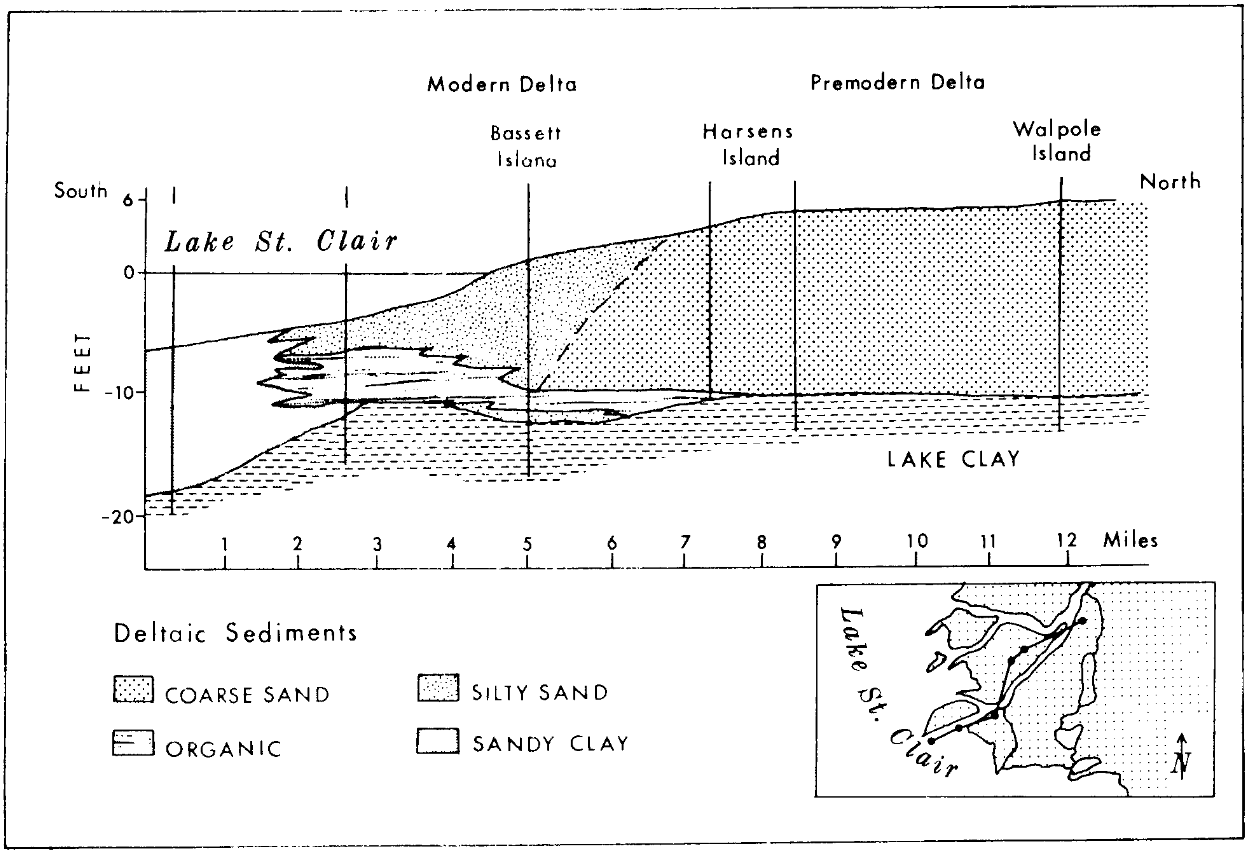

Figure 9. Cross-section of St. Clair Delta showing distribution of deltaic sediments.

available Carbon-14 data, the relative geomorphological events of the St. Clair Delta may be determined. Since the retreat of the Late Wisconsin ice sheet, the outlets of the Great Lakes, and hence lake levels in the St. Clair basin, have oscillated sufficiently to construct two deltas. Compared to other proglacial Great Lakes, Lake St. Clair was a less permanent feature as the lake bottom was exposed to subaerial modification due to the fluctuating ice sheet which determined lake level conditions (Figure 10).

One C-14 date retrieved from the upper portion of the lake clays, but beneath the premodern delta, indicates that both deltas are less than 7,300 ± 80 years old. Based upon older proglacial Great Lakes chronology, the premodern delta may have been deposited during the latter stage of Algonquin time (Wightman 1961). Additional C-14 dates have been obtained by Mandelbaum (1969). The dated materials range in age from 6,100 ± 80 to 9,300 ± 200 years. These organic materials do not appear to be _in situ_ and

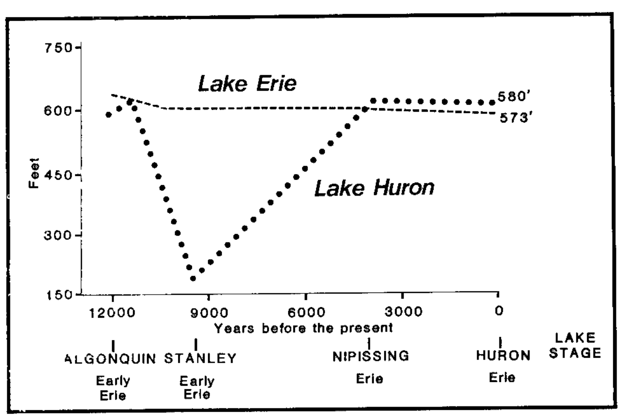

Figure 10. Chronology of lake levels and lake stages in the Huron and Erie basins (Dorr and Eschman 1970).

they have not been included in our interpretation. However, even if the latter dates were used they would not detract from our argument. Pezzetta (1968) also has radiogenic data that reveal that the minimum age of the delta sediment is 4,300 years before present (B.P.).

With the subsequent retreat of the ice during the Lake Stanley low-water stage, an outlet for the Lake Huron basin to the St. Lawrence was created via North Bay, Ontario. During this stage the premodern sands of the St. Clair Delta may have been exposed, oxidized, and dissected (Figure 10). Following the low-water stage, Lake Huron once again rose to the Nipissing stage and drained into the lower Great Lakes via the St. Clair River.

As determined by the more recent chronology, the premodern delta may have been deposited during Nipissing time some 3,500 to 5,000 B.P. and not during Algonquin time (Dorr and Eschman 1970). The premodern delta was deposited during a higher than present lake level and the subsurface sediments range in age from 7,300 to 9,300 B.P. It is suggested that following the Lake Stanley stage (i.e., Nipissing stage), the St. Clair River once again flowed south into Lake St. Clair and the premodern delta was deposited at an elevation slightly higher than the modern delta (Table 5).

On many coasts, evidence for lower than present sea levels is determined by depositional surfaces which dip beneath younger sediments (Shelemon 1971). Had the premodern delta been deposited during the Algonquin stage and the subsequent early Lake Stanley stage, evidence of that event as a depositional surface beneath the modern delta or as a paleosol should be apparent. Numerous borings suggest that the premodern delta does not plunge beneath the modern sediment. Since the stratigraphy implies that lake levels were lower than present only once, a Nipissing stage is favored for the deposition of the

Table 5. Interpretation of the events related to the origin of the St. Clair Delta.[a]

Approximate Dates B.P.	Lake stage	Event
3,500 to Present	Modern Lake St. Clair and Algoma Phase	Flow of Lake Huron continues southward; deposition of modern St. Clair River Delta and dissection of premodern surface
3,500 to 5,000	Lake Nipissing	Deposition of premodern delta approximately 1.5 m (5 ft) above present mean lake level
5,000 to 10,500	Lake Stanley	Lake St. Clair basin exposed; outlet for upper Great Lakes via North Bay, Ontario
10,500 to 12,500	Lake Algonquin and Post-Algonquin Phases	Valders Maximum

[a]Data sources: Dorr and Eschman (1970), Raphael and Jaworski (1982).

premodern delta. Organic deposits, commonly composed of large wood fragments (probably red ash) lie beneath both deltas. Assuming that the peat accumulated from organic growth above the water table, it probably was deposited during a low-water period prior to the Nipissing stage (possibly Lake Stanley).

Following the Lake Nipissing high level, Lakes St. Clair and Huron fell to their present levels. The premodern channels were slightly entrenched and the premodern surface oxidized during the last 3,500 years. Towards the apex of the premodern delta, beyond the areas of flooding, a mix of hardwoods has colonized the oxidized soils and evidence of drowning of a pre-Lake Stanley delta by Nipissing high water levels is lacking. With the fall to the approximate present lake level, the modern delta was deposited in Lake St. Clair.

Flow Regime and Sediments

Deltaic landforms occur where substantial quantities of clastic sediment are introduced and deposited into a receiving basin. Sediment is normally eroded from a drainage basin and transported down an alluvial valley by a master stream and its tributaries. Therefore the rate of delta development is dependent upon the flow regime and the availability of sediments.

The St. Clair River maintains a relatively stable channel and is not an alluvial stream in the common connotation. Fundamentally, the river is a strait connecting two large water bodies and therefore does not have a high variability of flow. Flow measurements during the ice-free season in 1959 revealed that discharge ranged from a low of 3,900 m^3/sec to a high of 5,700 m^3/sec. By contrast the Mississippi River flow between Baton Rouge and the Gulf of Mexico varies from a minimum of 1,400 m^3/sec to a maximum of 44,400 m^3/sec (Duane 1967). Therefore, for the St. Clair River, low flow was 68% of the high flow as compared to the Mississippi River where low flow was only 31% of the high flow. The discharge of the St. Clair River is relatively constant and averages about 5,097 m^3/sec (International Joint Commission 1981). Instead of a spring flood typical of most rivers, discharge in Lake St. Clair is slightly increased in late-summer when lake levels in Lake Huron are highest. Thus, overland flow and flooding is not an annual event and its occurrence is dependent in part upon seasonal lake level conditions.

Greatest delta extension occurs in areas of highest flow and sediment yield. Flow distribution data make it clear that the most active portion of the delta is presently confined to the western side of Lake St. Clair. Much of the flow of the St. Clair River is carried by the large distributaries on the American side of the delta. North, Middle, and South Channels account for approximately 95% of the flow volume whereas the principal Canadian distributary, Chenal Ecarte, accounts for 5%. Although North Channel appears to have been the main channel a century ago, construction and continual dredging of the St. Clair Cutoff Channel has increased the flow of South Channel.

Because the St. Clair River is not a true river system and has few tributary streams the source area for the deltaic sediments is not solely of fluvial origin. Rather, the principal source appears to be the shorelines of southern Lake Huron. Although some organic matter is carried in suspension, the clastic fraction is dominant. In terms of composition, quartz sand is the most common, but fragments of feldspar, chert, carbonate minerals, and igneous and metamorphic rock fragments also occur. According to Duane (1967), the mean diameter of the suspended river sediment ranges from 0.17 to 3.16 mm while the mean diameter of the bed load varies from 1.98 to 2.64 mm. Detailed sedimentological studies suggest that the shallow bays of the delta are composed of fine sand (0.115 mm) deposits and the sorting is fair (Mandelbaum 1966). It may be concluded that the St. Clair Delta is composed of sand-sized sediments. In contrast most marine deltas consist of a finer sediment fraction. Also where organic deposits occur on the delta surface or subsurface, they were formed in place and not transported into the delta complex.

Estimates of the sediment discharge rates were compiled by Pezzetta (1968) and

are summarized on Table 6. The high variability is probably a reflection of the time of sampling and of refinements in sampling and analytic techniques. Furthermore, the load is not distributed uniformly from one reach to another, a fact which accounts for the variable transport rates.

Under storm conditions there is a marked increase in the suspended load of the St. Clair River. The suspended sediment load is directly related to wind velocities and duration over southern Lake Huron. During periods of northerly winds the suspend load is decreased. River velocities are competent to transport material comprised of the beach sediment from southern Lake Huron. Sediment deposits in the nearshore zone of Lake Huron have a mean diameter of 0.125 mm to 0.25 mm; and according to Duane (1967), most clastic sediments suspended in the St. Clair Delta have mean diameters of slightly finer sizes. Particle size data suggest that the sediments of the delta are derived from reworked nearshore sediments in Lake Huron.

Soil Types

The soil types of the St. Clair wetlands reflect the late Quaternary history of the region and may be divided into two broad categories. The soils of the St. Clair Delta proper are derived from sources adjacent to Lake Huron whereas the soil types along the eastern shore of the lake are derived from lake plain sediments in southwestern Ontario. As such the delta soils generally have a coarser texture than the soils of eastern Lake St. Clair.

Table 6. Sediment discharge rates and characteristics in the St. Clair River.[a]

Transfer rate	Location	Load type	Sediment grade
54,700 m^3/year	Shore of Lake Huron at head of St. Clair River	Traction	Sand
61,600 m^3/year	St. Clair River at Bay Point Light (after storm)	Suspended	Silt-clay
37,500 m^3/day	St. Clair River bottom 12 km between St. Clair & Marine City (after severe storm)	Traction	Clay
40,100 m^3/year	St. Clair River Channel wall between St. Clair & Marine City	Traction	---
19,900 m^3/year	St. Clair River bank between St. Clair & Marine City	Traction	---
15,100 m^3/day	Surface and bottom of Chenal A Bout Rond, 3 km below North Channel (after a storm)	Total	Clay
15,200 m^3/year	Entire St. Clair River	Total	Sand

[a]Data sources: Cole (1903), Duane (1967), Pezzetta (1968).

The soils of the St. Clair Delta were derived from the shoreline and nearshore zone of Lake Huron. The sediment was transported by the St. Clair River and now forms the delta proper. Two soil types are evident in the delta. At the apex of the landform, 1.5 to 2 m above mean lake level, Sanilac loam (Colwood fine sandy loam in Ontario) is prevalent. This soil is a very fine sandy loam and occurs on moderate (0-2%) slopes. The soil formed in limey, water-laid sediment of very fine sandy loam and loamy very fine sand (U.S. Department of Agriculture 1974). Although the surface layer is dark-brown (0-15 cm), sand pits reveal that the deeper soil is yellowish-brown (Munsell color code = 10 YR 5/6), a fact suggesting slight oxidation. This soil type represents a premodern delta that was formed at higher lake levels in the geologic past.

The wetlands proper are characterized by the Bach loam ("marsh" soils in Ontario). The soil has a very fine sand loam texture which formed in limey lacustrine sediments (Figure 11). Occurring on land with a slope of 2% or less, the soil is often water logged. In a typical profile the surface layer is black, calcareous, very fine sand loam, 18 cm thick. The subsoil is 75 cm thick and is made up of several layers of gray, calcareous, very friable, very fine sand loam. It represents the modern delta front, local depressions, and ancestral channels of the St. Clair distributaries.

The Clyde loam is a poorly drained loam occupying the eastern shoreline of Lake St. Clair. It is characterized by 0 to 20 cm of very fine, very soft, very dark gray silt-clay with large quantities of organic debris. From 20 to 30 cm deep, Clyde loam is dark gray, fine, firm silt and clay (Mudroch 1981). This soil type developed on older, more fine-grained sediments of a lake plain and is therefore finer and generally has a higher organic content than the delta soils.

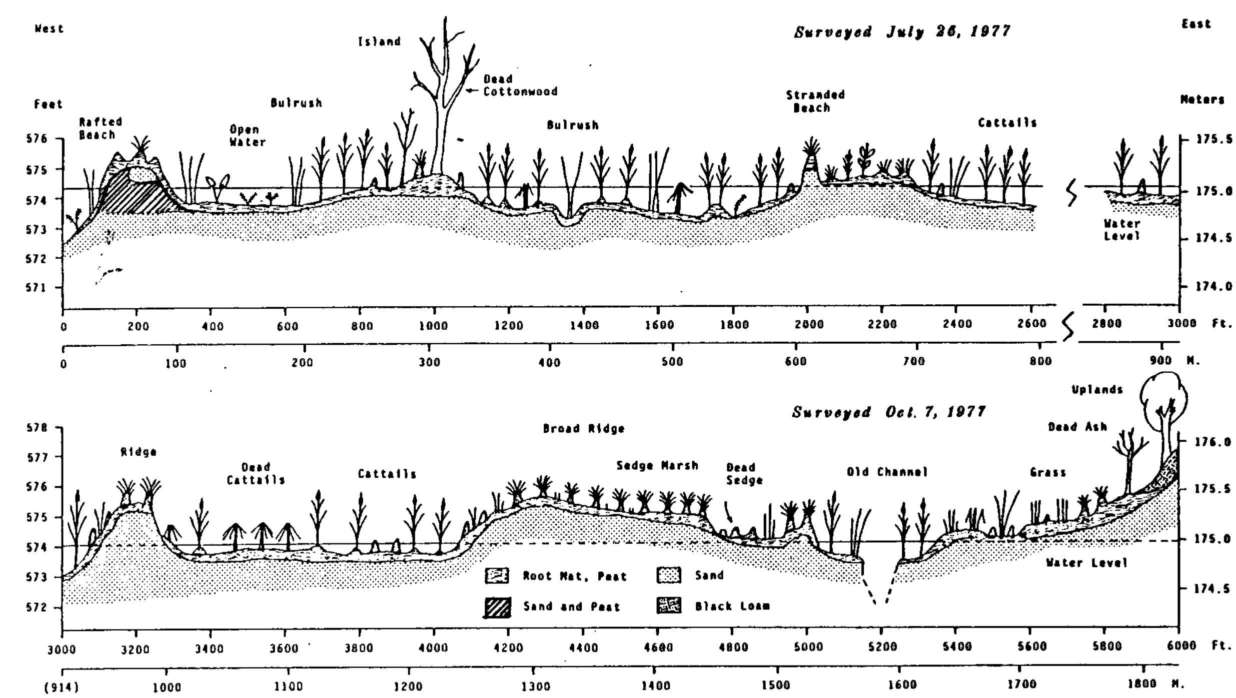

Figure 11. Vegetation transect on Dickinson Island, St. Clair Delta, showing character of wetland soils (Jaworski et al. 1981).

The soils in the Lake St. Clair region are basically derived from unconsolidated sediments deposited over bedrock in early Holocene time (i.e., past 20,000 years). These soils contribute to the geochemical composition of bottom sediments of the wetlands. Typically, the wetland sediments investigated by Mudroch (1981) are submerged mineral soils, with a pH ranging between 6.9 and 7.2. The wetland sediments from the Walpole Island sector of the delta are coarser; more than half of the particles are at least sand size whereas the eastern shore of Lake St. Clair silt size particles are dominant.

The absence of extensive peat or organic rich soils is noteworthy. Peat accumulations are poor and were probably formed in place rather than transported into the wetlands. Deltaic wetlands are often characterized by blanket peat deposits especially in sheltered localities such as bays and backbarrier flats. In the Great Lakes coastal wetlands, peats are with few exceptions (e.g., western Saginaw Bay) uncommon. This suggests several possibilities: 1) wetlands during recent geologic time were not abundant, or 2) peat deposits decomposed rapidly or, 3) water exchange between the wetlands and lake was efficient in exporting organic material. In any case, clastic sediments are dominant in the wetland soils of Lake St. Clair.

2.2 CLIMATE AND WEATHER

The variable weather elements such as wind, precipitation, air temperature, humidity, and growing season influence the physical and biological character of Lake St. Clair. A unique aspect of this water body is rapid water level change due to seiches or wind tides. Also, spring ice jams can significantly alter the water level of the lake.

Climatic Setting

The climatic variables such as temperature, wind, atmospheric pressure, and precipitation play a significant role in the terrestrial and lacustrine environment of Lake St. Clair. These elements are primarily responsible for the water budget of the lake as well as wave activity, the extent of the growing season in the wetlands, the distribution and length of ice cover, and the water level conditions on a daily, monthly, and seasonal basis.

The climate of the lake is characterized by cold winters (coldest month below $0^{o}C$ and warm summers (warmest month above $22^{o}C$) with precipitation uniformly distributed through the year (climate type Daf based on the Koppen system). Cyclonic storms occur through the year, but decrease in frequency during late June, July, and August. During this time convectional uplift is frequent and thunderstorms are common. Most of the moisture that falls on the Great Lakes basin as precipitation originally evaporated from the tropical Atlantic Ocean or the Gulf of Mexico (Phillips and McCulloch 1972). On an average day, 10 billion m^3 of water in the form of water vapor are advected across the Great Lakes basin. The efficiency of precipitation mechanisms is such that only about 15% or 1.4 billion m^3 fall as rain on a given day.

The frost-free season is defined as the interval in days between the last occurrence of frost in spring and the first occurrence in fall and is thus an indicator of the length of the growing season. The mean annual frost-free period for Lake St. Clair is 160 days. With the exception of the south shore of Lake Erie, Lake Ontario, and the south shore of Lake Michigan, which experience 180 frost-free days annually, Lake St. Clair has the longest frost-free period in the Great Lakes basin. The spring cooling exerted by the lake prevents premature growth of the vegetation thus lessening the chances of crop loss due to late spring frosts (Eichenlaub 1979). Conversely, the slow cooling in autumn retards the occurrence of the first fall frost thus extending the growing season.

Closely related to the length of the frost-free season is the accumulation of growing degree days as an index of the amount of heat available during the growing season. The index is usually defined as the number of degrees of mean daily temperature above a base of $5.6^{o}C$.

The growing degree-day concept has been applied to delimit areas suitable for particular vegetation types and as a means of predicting the hatching date of various insects (Baker and Strub 1965). On the basis of using mean monthly temperature and the number of days in a month, the accumulated number of degrees above a base of 5.6°C in a normal year is 2,340 °C in the southern portion of Lake St. Clair and 2,200 °C in the northern sector of the lake.

Table 7 reveals that the mean annual average air temperature for three selected stations is 9.4°C. Mean monthly temperatures in January and February are well below freezing (-3.5°C) but summer means exceed 22°C. Such continental conditions commonly occur in regions which are remote from maritime air masses.

One of the characteristics of the climate of the Great Lakes is the lack of any marked seasonality of precipitation. Mean monthly precipitation values for three stations (Table 8) average 77.83 cm. It should be noted that the Detroit and Windsor stations are located in highly urbanized areas compared to the Mount Clemens station. As noted on the table, the precipitation is lowest at Mount Clemens. Research in urban precipitation patterns indicates that the presence of a large city such as Detroit does cause an increase in precipitation in the urban areas (Sanderson 1980). Therefore, Mt. Clemens is more representative of temperature conditions over Lake St. Clair.

Wind direction and frequency are significant with regard to waves, ice jams and short term (i.e., seiches) water level changes in Lake St. Clair. According to Ayres (1964), the circulation in Lake St. Clair is strongly influenced by prevailing wind direction as are longshore currents. Figures 12 and 13 illustrate the average monthly directional frequency of winds for Windsor and Mt. Clemens respectively. The more spherical wind roses (e.g., March, April) have the greatest variability in wind direction. The more skewed wind

Table 7. Mean monthly temperatures for three selected stations.[a]

Month	Mount Clemens, Michigan 1940-1969		Detroit City Airport 1940-1969		Windsor Airport 1941-1970	
	°F	°C	°F	°C	°F	°C
January	24.1	-4.3	26.9	-2.8	24.3	-4.3
February	25.4	-3.6	27.2	-2.7	25.8	-3.4
March	33.7	0.5	34.8	1.6	34.2	1.2
April	46.2	7.8	47.6	8.6	46.8	8.2
May	56.5	13.4	59.0	15.0	57.2	14.0
June	67.5	19.7	69.7	20.9	67.9	19.9
July	72.0	22.2	74.4	23.6	72.1	22.3
August	70.3	21.3	72.8	22.7	70.4	21.3
September	62.9	17.2	65.1	19.4	63.4	17.4
October	52.7	11.5	53.8	12.1	52.9	11.6
November	39.8	4.3	40.4	4.7	39.8	4.3
December	28.4	-2.0	29.9	-1.2	28.4	-2.0
Annual average	48.3	9.0	50.1	10.1	48.6	9.2

[a]Data sources: Sanderson (1980); U.S. Dept. of Commerce, Weather Service.

Table 8. Mean monthly precipitation for three selected stations.[a]

Month	Mount Clemens Michigan 1940-1969		Detroit City Airport 1940-1969		Windsor Airport 1941-1970	
	inches	cm	inches	cm	inches	cm
January	1.66	4.21	2.05	5.21	2.18	5.54
February	1.72	4.37	2.08	5.28	2.05	5.21
March	2.15	5.46	2.42	6.15	2.61	6.63
April	2.76	7.01	3.00	7.62	3.19	8.10
May	3.04	7.72	3.53	8.96	3.27	8.31
June	3.17	8.05	2.83	7.19	3.29	8.36
July	2.36	5.99	2.82	7.16	3.26	8.28
August	2.80	7.11	2.86	7.26	3.24	8.23
September	2.12	5.39	2.44	6.20	2.39	6.07
October	2.13	5.41	2.63	6.68	2.49	6.32
November	2.02	5.13	2.21	5.61	2.44	6.20
December	2.14	5.44	2.08	5.28	2.50	6.35
Annual average	28.07	71.29	30.95	78.60	32.91	83.59

[a]Data sources: Sanderson (1980); U.S. Dept. of Commerce, Weather Service.

roses (e.g., June, July, August) reveal a more prevailing wind. It is evident that predominant winds in the region are from the westerly direction, especially from the southwest quadrant. Additional wind data for Windsor airport suggests that January, February, and March have the highest wind speeds averaging 20 km/hr while June, July, and August have the lowest at 13 km/hr. Furthermore, winds from the west-northwest have the highest speeds at 21 km/hr, and the lowest wind speeds, 13 km/hr, are from the southeast.

Ice Cover

A major physical feature on Lake St. Clair is the occurrence of ice. Using 20 years of data, Assel et al. (1983) documented and mapped the distribution of ice on the Great Lakes. The concentration of ice varies over the period of record mainly because of the shallowness of the lake. Although synoptic data on ice thickness especially over the central portion of Lake St. Clair are poor, maximum thickness during severe winters is approximately 49 cm and maximum thickness during mild winters is about 5 cm. Normally during mid-December through February the lake is ice covered with the exception of its exit--the Detroit River. During mild winters the only persistent ice cover in January and February occurs along the eastern shoreline of the lake. However, during severe winters persistent ice will cover 100% of Lake St. Clair from mid-December to mid-April.

The impact of ice and ice jams on wetland vegetation is poorly understood, and can have negative as well as positive effects. Ice jams migrating down distributary channels uproot aquatic and persistent vegetation from the substrate. Conversely, ice in the nearshore zone protects lacustrine wetlands by acting as a buffer and absorbing the impact from incoming waves. The coastal protection offered by the ice in the nearshore zone is particularly significant during mild winters when most of the lake is not frozen and also during the spring when storms frequently occur and wave energies are higher.

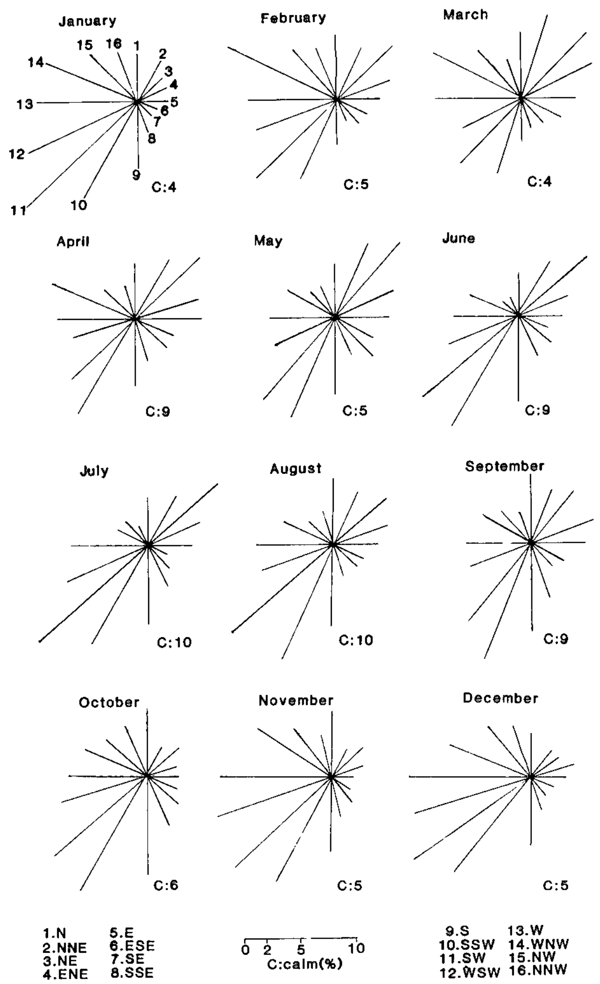

Figure 12. Monthly wind frequency diagrams for Windsor, Ontario, 1955-1972 (Sanderson 1980).

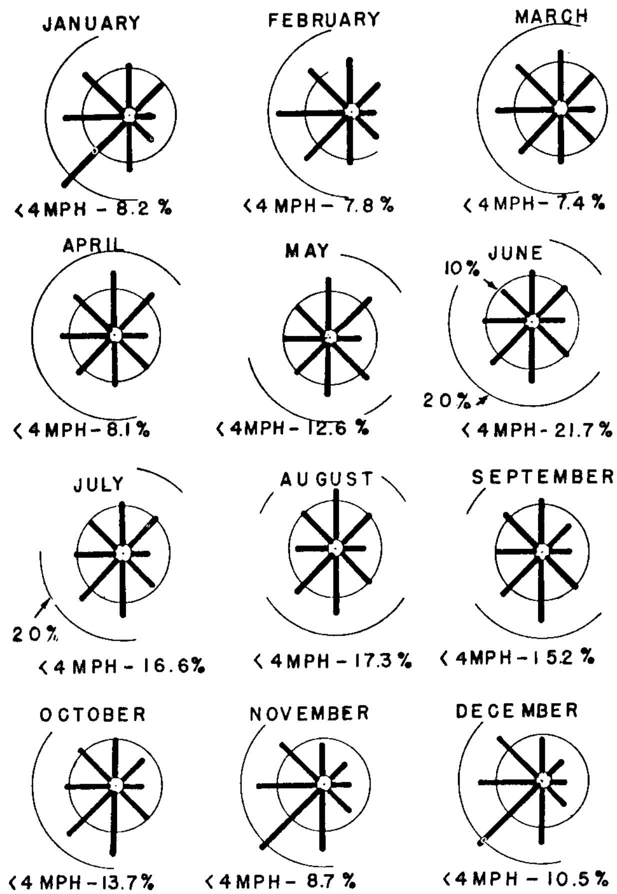

Figure 13. Monthly wind frequency for Mt. Clemens, Michigan (Selfridge Air Force Base) for period 1936-1953 (Ayers 1964). Note only velocities greater than 4 mph plotted; winds less than 4 mph shown as percent time.

2.3 HYDROLOGY

Historically water levels of Lake St. Clair have ranged approximately 1.7 m in response to changing water budgets. Water budgets in turn are related to inflow and outflow as well as evaporation and precipitation. The impact of changing water levels within the basin on the shoreline and wetlands has been significant. Historical wetland displacements have been documented with the use of aerial photography over time. Wetland vegetation transects and geographical distributions over time have also been determined.

Circulation in Lake St. Clair

Investigations reveal that two major water masses occur in Lake St. Clair. Ayres (1964) modeled field data before and after the construction of the St. Clair Cutoff Channel and found that the current structure in the lake maintained semi-permanent patterns. The distribution pattern was altered according to changing wind patterns. Leach (1980) also identified two discrete water masses in the lake on the basis of cluster analysis of physical and chemical data.

The main flow of water entering Lake St. Clair is from the St. Clair River.

This river contributes about 98% of the total inflow to the lake. The construction of the St. Lawrence Seaway and the opening of the South Channel Cutoff in 1962 have increased the proportion of St. Clair River water arriving directly into the main lake basin. The greater cross-sectional area of the Cutoff Channel for outflow which now exists and the straightening that the artificial channel provides have decreased the frictional effects and promoted a greater discharge of the St. Clair River water directly into the main basin.

In Lake St. Clair the extent and geometry of the circulating water masses are related to wind direction. The predominant winds in the region are from the southwest quadrant (Sanderson 1980). Figure 14-D illustrates the two principal patterns in the eastern and western portion of the St. Clair basin derived from prevailing southwest winds. Figure 14-A reveals a more distinctive circulatory pattern associated with a north wind. Based upon Ayres' (1964) model, water in Anchor Bay originates from two distinct sources. With southwest winds there are both a net diminution of outflow through North Channel and the creation of a discrete gyre in Anchor Bay composed of Clinton River water. With a north wind, though, Anchor Bay becomes dominated by water from the North Channel of the St. Clair River as the Clinton River water is reduced in the bay.

The significance of the two main water masses is their relationship to the productivity of the lake. The water mass adjacent to Ontario is more influenced by nutrient loadings from the Sydenham and Thames rivers and the smaller tributaries from Ontario. These waterways drain an intensively cultivated lake plain. Urban development on the south shore of Lake St. Clair also contributes to the loading. Because this water mass is more enriched and more stable than the mass associated with St. Clair River water, it has yielded greater productivity (Leach 1972, 1973).

Due in part to the flushing time of Lake St. Clair, which is theoretically about 9 days, the fish communities have changed little, with the exception of some coldwater species. According to Johnston (1977), the walleye and the yellow perch stocks over the past century have remained reasonably stable in spite of more intensive agricultural practices in the watershed, increased settlement in the coastal zone, and exploitation of the resource from commercial fisheries. The flushing action of relatively clean water from Lake Huron has prevented concentration of nutrients and eutrophication in most of Lake St. Clair.

Water Discharge Into Lake St. Clair

In addition to the principal source of water from the St. Clair River, several other river basins contribute water to the lake, including the Black, Belle, Clinton, Thames, and Sydenham Rivers (Figure 15). The St. Clair River is not a true fluvial system but rather a strait connecting two large water bodies (Lake Huron and Lake St. Clair). It therefore does not exhibit typical river discharge characteristics. Furthermore, depositional processes associated with rivers are normally directly linked to extreme flow regimes. But St. Clair River flows and ultimate sediment distribution in the St. Clair Delta are more closely linked to ice conditions or high lake level conditions.

Of the total average fall of 2.5 m from the Lake Huron level to Lake Erie, 1.5 m occur in the St. Clair River (Korkigian 1963). Its banks and bed have been relatively stable except for navigation improvements, and sand and gravel dredging over several decades. Figure 16 illustrates mean monthly discharge from 1900 through 1980 (Quinn and Kelley 1983). Average monthly discharge is 5,121 m^3/sec and the range of discharge is 4,254 m^3/sec (February) to 5,483 m^3/sec (September). Detailed monthly data are included in Appendix B. With flow velocities up to 3.2 km/hr the travel time through the system is relatively high. As determined by Derecki (1983), the flow time of water from the international bridge at Port Huron to Lake St. Clair is 21.1 hours (Table 9). The flow time through the Detroit River (Belle Isle south to Celeron Island) is 20.9 hours. The initial travel timetable was developed for normal flow conditions.

Based on the geomorphologic history of the St. Clair Delta, the most active portion of the landform at the present time is to the west. As the St. Clair River enters the St. Clair basin it bifurcates near Algonac into the North and South channels, which in turn each split before entering Lake St. Clair. The flow is therefore proportionally distributed through the channels as illustrated in Figure 17.

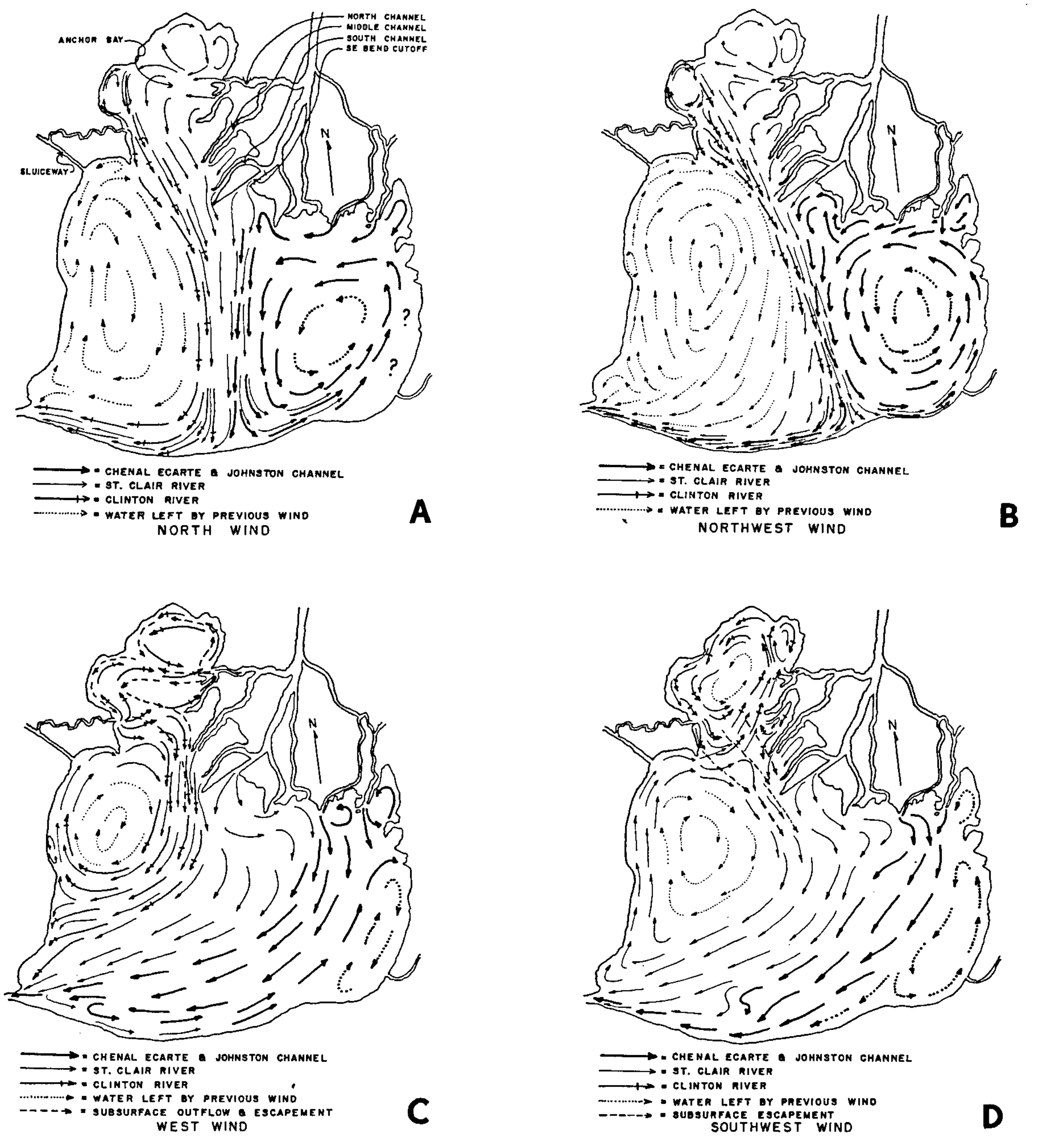

Figure 14. Current patterns for Lake St. Clair under various wind conditions (Ayers 1964).

Artificial modification in the past 85 years has altered river levels and the water volume in Lake St. Clair. Artificial channel changes in the St. Clair River since 1900 include dredging for commercial gravel removal between 1908 and 1925, and uncompensated navigation improvements for the 7.7-m and 8.3-m projects completed in 1933 and 1962 respectively (Derecki 1982). These channel changes increased the discharge through the St. Clair River and caused a

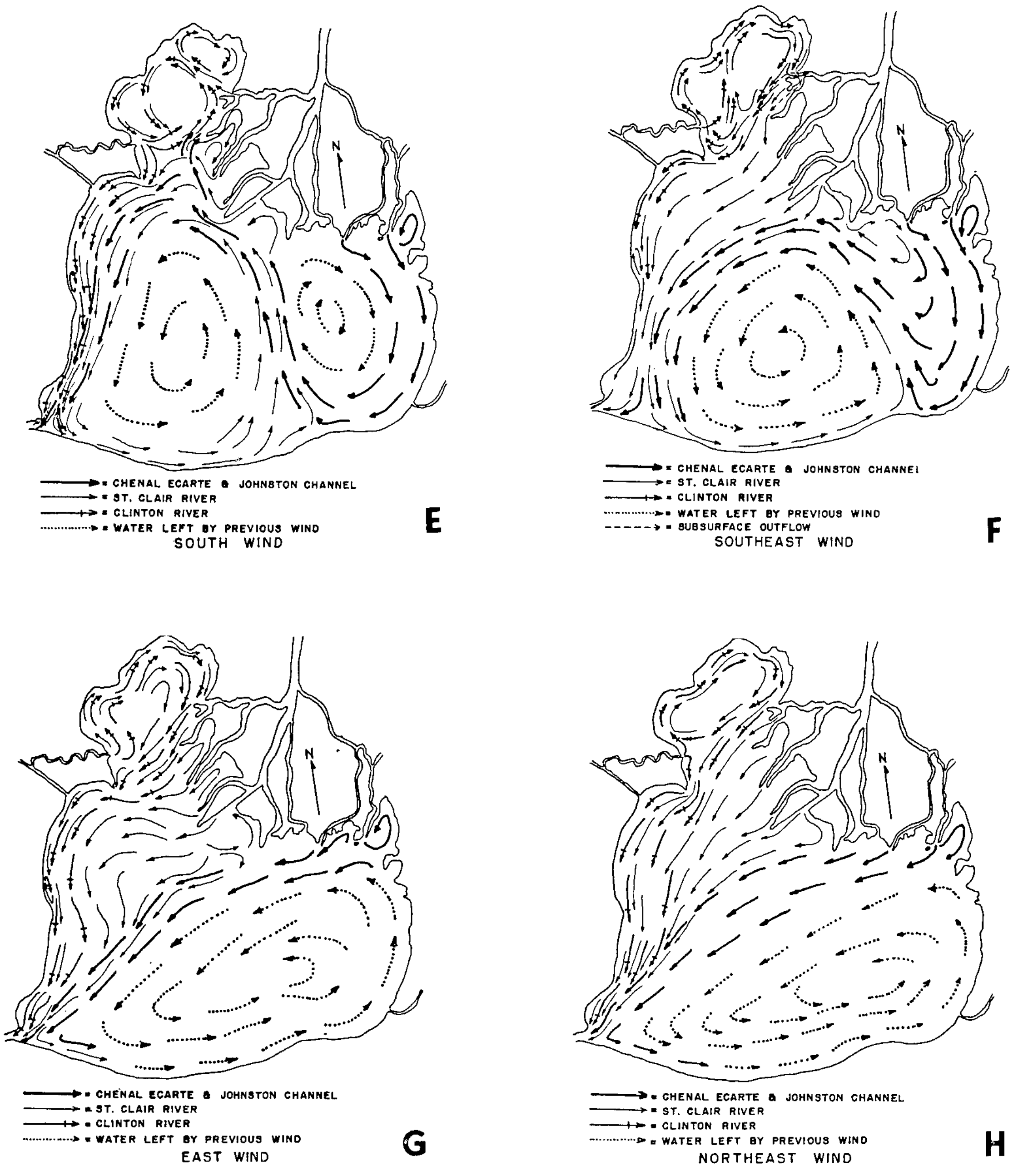

Figure 14. (Continued)

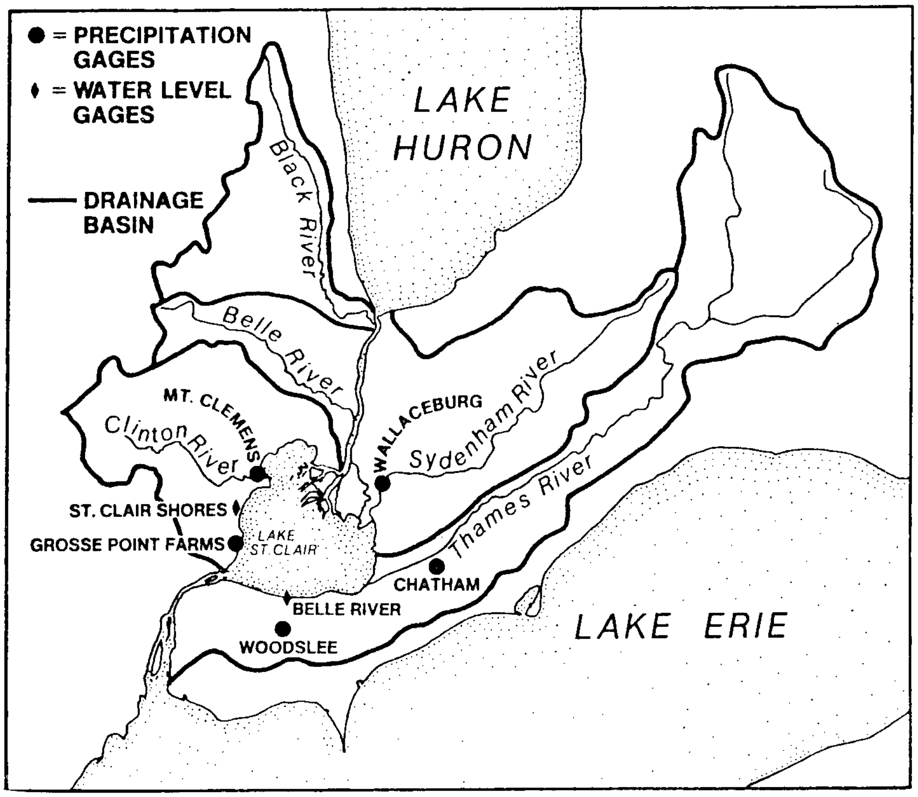

Figure 15. Lake St. Clair-St. Clair River drainage basin showing location of precipitation and water level gages.

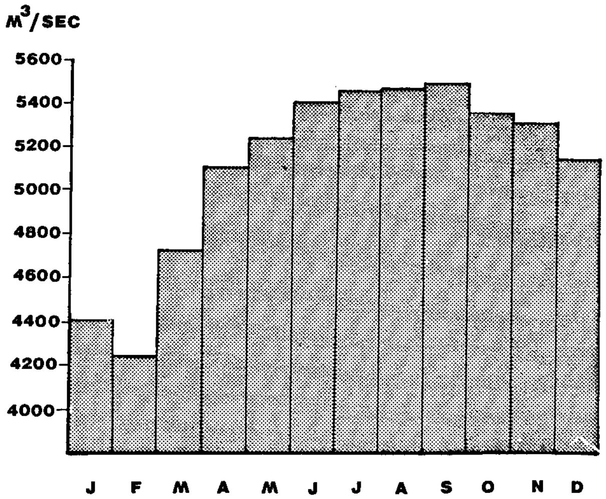

Figure 16. Mean monthly discharge of the St. Clair River 1900-1980.

Table 9. St. Clair River flow time and velocity from Lake Huron to Lake St. Clair.[a]

Station	Time (hr)	Distance (km)	Velocity (km/hr)
Lake Huron	0.0	0.0	
Blue Water Bridge	0.1	0.6	6.0
Black River	0.9	3.7	3.9
Stag Island	4.4	13.7	2.9
St. Clair City	6.0	22.9	5.8
Marine City	9.8	36.8	3.7
Roberts Landing	12.0	42.5	2.6
Algonac Lt.	12.5	44.3	3.6
St. Clair Cutoff	17.9	57.0	2.4
Lake St. Clair	21.1	60.5	1.1

[a]Data source: Derecki (1983).

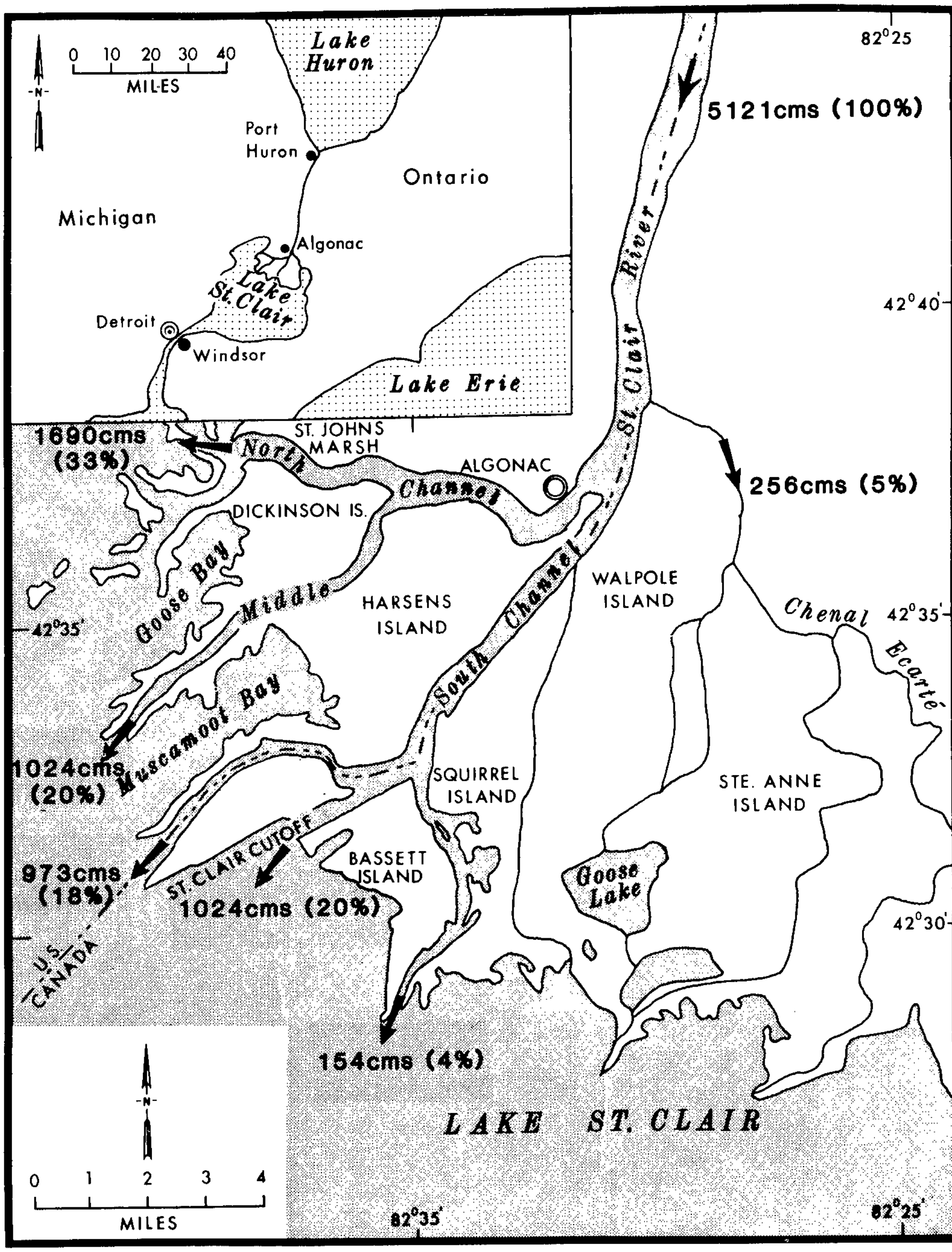

Figure 17. Location map of St. Clair Delta distributary channels showing average discharge (cubic meters per second) and flow distribution (percent of total).

permanent lowering of the lake's level. The impact of these channel changes resulted in the lowering of the Lake Michigan and Lake Huron water levels by 0.27 m. This depth superimposed on the combined areas of Lakes Michigan and Huron represents a permanent water loss of 32 km^3 or nine times greater than the volume of Lake St. Clair.

Lake St. Clair Water Levels

Lake level changes and their duration play an important role in the character of Lake St. Clair, its shoreline and its wetland communities. In general, high and stable water levels are most beneficial to the fish stock of the lake whereas low and stable or unstable conditions are least desirable from an ecological standpoint. Conversely higher water levels when combined with storm events encourage higher flood frequencies and coastal erosion. The wetland communities of Lake St. Clair respond to longer term water changes and hence adjust to such changes over time.

All the Great Lakes including Lake St. Clair experience changes in water levels due to short-term and long-term weather and climatic conditions. Short-term changes are due to steep barometric gradients which may alter water levels for a period of several hours. During the winter months ice jams on the St. Clair River cause abrupt water level changes which may span a period of 60 days. Long-term oscillations are related to water input and water output to and from Lake St. Clair. Such water level changes, although non-cyclic, occur over a period of several years. Pre-1946 storm surges on Lake St. Clair and its connecting channels have been documented by Murty and Polavarapu (1975) and are summarized in Table 10. As noted, the water levels at Tecumseh, Ontario dropped 0.5 m and rose again over a period of approximately 48 hours. Short-term depressions of water levels due to storm surges provide some flushing action and the introduction of nutrients from the marshes into the bays and nearshore waters of the lake. However, the event is probably too short-lived to have significant positive impact.

Table 10. Record storm surge levels of Canadian stations on Lake St. Clair and connecting channels.[a]

Date of storm	Observation station	Maximum surge (m)	Maximum surge (ft)
November 1913	Fighting Island[b]	0.48	1.56
	Isle Aux Peches[c]	0.28	0.91
October 1916	Fighting Island[b]	0.71	2.34
	Isle Aux Peches[c]	0.51	1.67
November 1940	Tecumseh[d]	0.54	1.76

[a]Data source: Murty and Polavarapu (1975).
[b]Lower Detroit River.
[c]Upper Detroit River.
[d]Lake St. Clair.

Ice jams are a common occurrence on the St. Clair River and often detain interlake shipping. Ice blockades usually form in February and March in the St. Clair River and occasionally extend into April. On the average, ice retards the flow by 16%. Ice-jamming reduces the outflow from Lake Huron and raises its level and at the same time reduces inflow to Lake St. Clair and lowers its level. During the winters of 1904-1905 and 1905-1906, average inflow from Lake Huron to Lake Erie decreased 1,369 m^3/sec over 4 months and 904 m^3/sec over 5 months, respectively (Bajorunas 1968).

During the spring of 1984, strong winds from the east and north caused a massive ice jam south of Lake Huron. Brash ice clogged the 62.5 km-course of the St. Clair River until the end of April, and jams of 3 m or more in depth developed at the apex of the delta. This situation led to a decrease in discharge from the monthly average of 5,096 m^3/sec for April, to about 2,500m^3/sec below the projected mean volume for that month. Also there was a subsequent drop in the Lake St. Clair water level by more than 0.76 m from March 21 to April 19 (175.40 to 174.59 m above mean sea level). In the closing days of April a convoy of Canadian and American ice breakers, aided by unseasonably mild temperatures broke the ice jam at the upper end of the St. Clair

Delta allowing 70 vessels anchored in the Detroit River and western Lake Erie to enter the upper Great Lakes.

Figure 18 records the impact of this ice jam in the St. Clair River on the water level of Lake St. Clair. Water level began its drop in mid-March 1984 and did not recover until the end of May 1984. The change (March 15-April 15) in the water level was 0.48 m. Ice jams temporarily alter the hydrology of the St. Clair Delta. As the distributary channels are jammed, river water is diffused through crevasses into the bays (e.g., Muscamoot and Goose Bays). This process is responsible for subaqueous sedimentation in the bays and the subsequent colonization by emergent wetlands.

February 1984 was relatively mild and Lake Huron was largely ice free, but exceptionally cold weather followed and an ice cover formed over the entire lake by about March 10th (Great Lakes Commission 1984). By the outset of April, Lake Huron again was nearly ice free except at the head of the St. Clair River. Unusually strong and persistent westerly winds reduced the movement of drifting ice down the river by blowing much of it from the south end of Lake Huron eastward. Following this event, winds from the east and north forced the jumbled ice into the St. Clair River over a 3-week period.

Water level data for Lake St. Clair have been continuously recorded since 1899. The long-term level of the lake is determined by the inputs of water derived from runoff or inflow of connecting channels and tributaries to the lake, and precipitation over the lake basin. The outputs are due to evaporation and outflow via the Detroit River. Long-term lake level oscillations are usually thought of as volumetric changes which are climatically controlled. Changes in lake storage may be summarized as follows:

$$S = (P-E) + (I-O)$$

where: S = change in storage volume
P = precipitation
E = evaporation
I = inflow
O = outflow

Although non-cyclic, the water levels appear to have a high water period and a low water period every 7 to 10 years.

Water volume and lake level of a given lake basin are dependent upon water inflow and outflow, which in turn is determined by factors such as overwater precipitation, evaporation, and runoff into and out of the basin. These factors are interrelated and may be expressed as a transfer factor. The transfer factor is defined as the sum of the monthly precipitation and runoff minus the evaporation and change in storage. Quinn (1976) computed transfer factors for Lake St. Clair (Table 11). The runoff from the land into Lake St. Clair was determined independently for the four river basins draining into the lake. They are the Belle, Clinton, Thames, and Sydenham Basins (Figure 15). On an annual basis and during most of the year, the transfer factor is most sensitive to runoff. The evaporation however, becomes the most important factor during the high evaporation months of August to October.

Figure 18 records the water level history of Lake St. Clair for 1900 to 1984. The lake has a mean monthly elevation of 174.87 m above sea level at Father Point, Quebec in the Gulf of St. Lawrence. However, as the figure demonstrates, the water level in recent years has been well above this level. Table 12 indicates that the lake has had a record high of 175.64 m (June 1973) and a record low of 173.71 m or a range of 1.93 m. Low water or chart datum is 174.25 m. This level is a fixed reference plane selected by the United States and Canada so that the majority of time during the navigation season the Great Lakes actual levels will be above that plane. Water levels are lowest in February; based on a 1900-1983 mean, the level for this month is 174.47 m. Highest water levels occur in July; the 1900-1983 average for this month is 174.94 m.

Lake level fluctuations occur naturally on Lake St. Clair and are the result of prolonged periods of precipitation, drought, storm-related events, or ice conditions. The lake level depends on the balance between the total water supplied to the lake from precipitation on

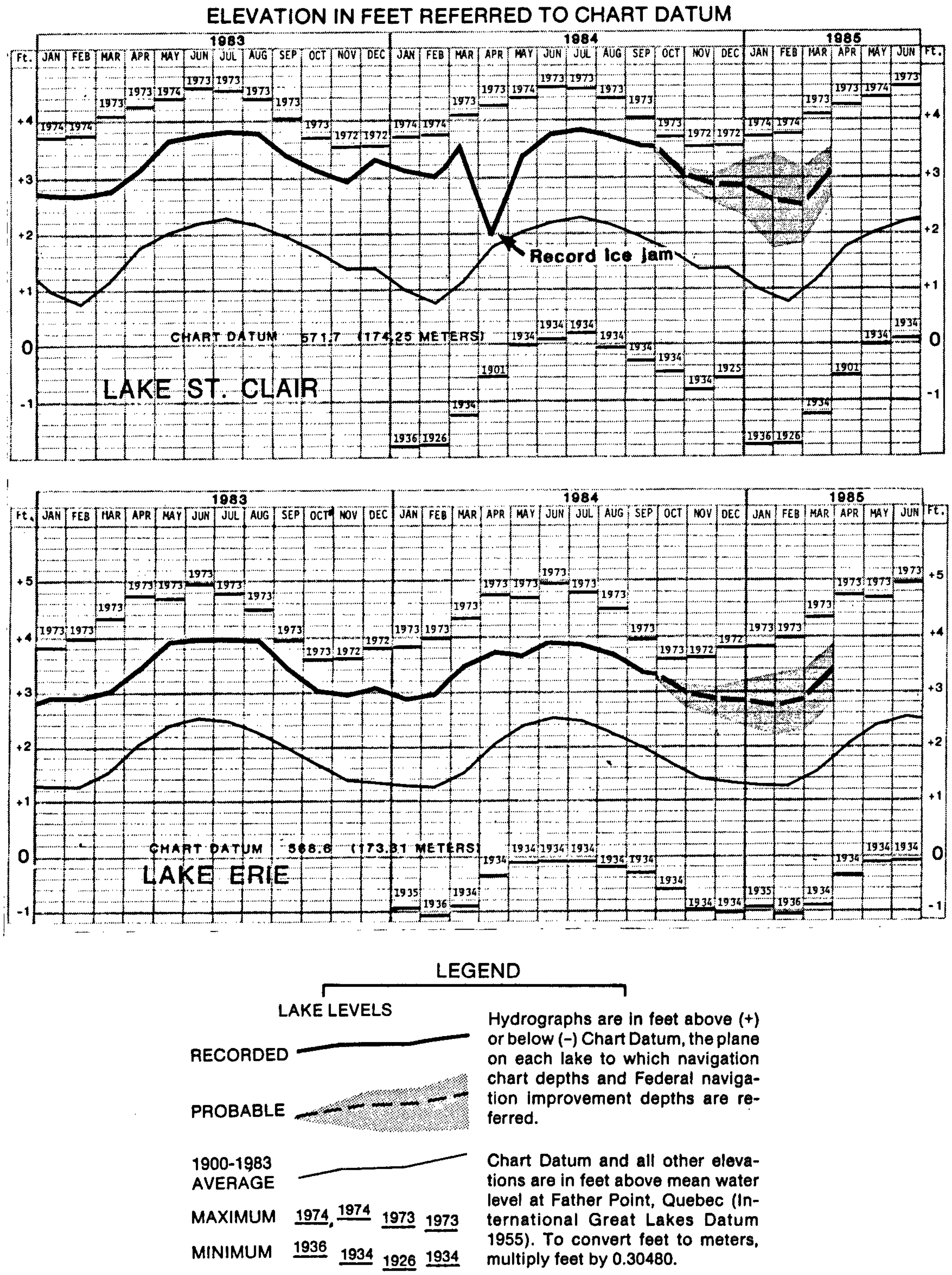

Figure 18. Hydrograph of Lake St. Clair and Lake Erie water levels, showing the impact of a record ice jam in the St. Clair Delta in March and April 1984 (U.S. Army Corps of Engineers). Note the slight dip in Lake Erie water levels in May in response to the St. Clair Delta ice jam.

Table 11. Lake St. Clair average monthly water transfer factor parameters.[a]

Parameter	J	F	M	A	M	J	J	A	S	O	N	D
	Cubic meters per month											
Precipitation	23	20	25	34	25	34	31	31	25	23	28	28
Tributary runoff	156	190	342	277	136	62	37	28	25	42	79	153
Lake evaporation	25	25	11	8	48	37	34	45	59	51	42	20
Change in storage	-76	42	79	42	17	17	-6	-17	-37	-40	-25	14

[a]Data source: Quinn (1976).

Table 12. Water level data for Lake St. Clair.[a]

Parameter	Meters	Feet	Remarks
Low water datum	174.25	571.70	
Monthly water levels			
Average	174.87	573.72	1900-1983 data base
Record high	175.64	576.25	June 1973
Record low	173.71	569.90	January 1936

[a]Data source: U.S. Army Corps of Engineers.

the lake and runoff from the surrounding drainage area and the amount of water discharged from the Detroit River or by evaporation. The relationship between long-term changes in lake level and the climatic events which cause the changes is usually quite evident, even though there is generally a time lag in the response of lake levels to imbalances in the system. The high levels of 1973 on Lake St. Clair as well as the other Great Lakes were attributed to a 16% increase in precipitation and a 24% decrease in evaporation during 1972 compared to the long-term average for both precipitation and evaporation.

2.4 WATER QUALITY

Lake St. Clair waters are usually well mixed by both horizontal and vertical currents. The two major factors affecting current patterns and water quality are the flow-through current of the St. Clair River (Figure 19) and the seasonal water temperature changes. Variations in water density, largely caused by changes in the water temperature and amount of suspended solids, and winds affect the lateral movement at the lake surface, while turbulence created by storms, and recreational and commercial boating activities affect the vertical movement (U.S. Army Corps of Engineers 1974).

Water quality information is presented here in terms of nutrients and contaminants which either enhance or limit wetland productivity. Of particular concern are phosphorus, nitrogen, dissolved oxygen, alkalinity, pH, major ions, trace elements, and toxic organic compounds. Thermal structure, light penetration, and sediment load are also addressed in terms of impacts to wetland stability and habitats.

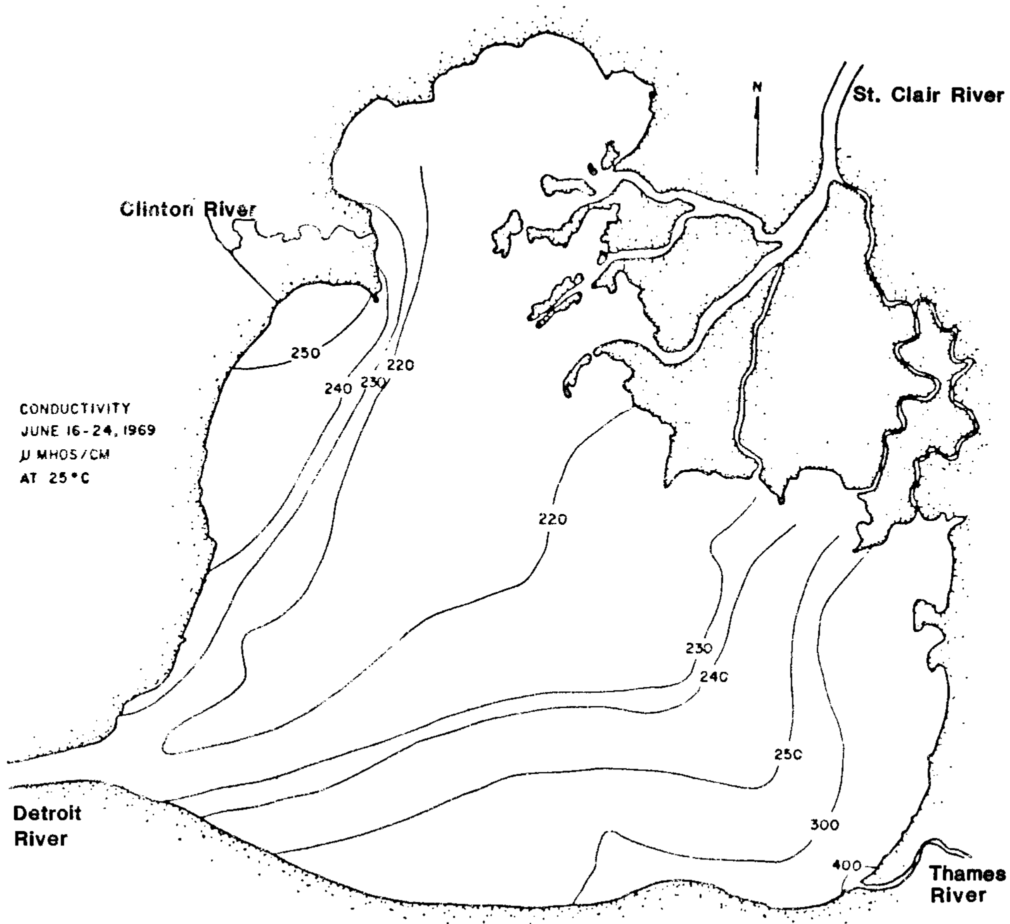

Figure 19. Distribution of specific conductance in Lake St. Clair (Bricker et al. 1976). Note low values from the St. Clair River and high values at the mouths of the Thames River and Clinton River.

In March 1970 the Canadian government announced that 5,500 kg of commercially caught walleye (Stizostedion v. vitreum) from Lake St. Clair were destroyed because of mercury contamination. In the early 1970s, mercury concentrations in fish in Lake St. Clair ranged from 0.3 ppm to over 5 ppm, the higher values were usually found in larger fish and in predacious species. The United States and Canada adopted a concentration of 0.5 ppm in fish muscle as a maximum for commercial fish. Both governments closed commercial fishing in the St. Clair River and Lake St. Clair, as well as walleye fishing in western Lake Erie.

The mercury pollution was largely attributed to waste discharges from chlor-alkali processing plants on the St. Clair and Detroit Rivers which began operation in the 1950s. Several of these plants ceased operation in the early 1970s and as a result, mercury contamination has diminished in the environment. Levels of total mercury in walleye collected in Lake St. Clair have declined from a mean of over 2 ppm in 1970 to 0.5 ppm in 1980. In western Lake Erie, 1968 levels of mercury were 0.8 ppm as compared to only 0.3 ppm in 1976. The rapid environmental response subsequent to the cessation of major point source discharges at Sarnia, Ontario, and

at Wyandotte, Michigan, can be attributed to rapid flushing by the St. Clair-Detroit Rivers system and rapid burial of contaminated sediments by the high load of suspended sediment delivered to western Lake Erie.

Few comprehensive water quality investigations have been conducted on Lake St. Clair and measurements in the coastal wetlands are rare. The Michigan Water Resources Commission (1975) conducted a thorough study of the open lake and bays along the American shore in 1973 (Table 13) and Leach (1972, 1973, 1980) reported on conditions in Canadian waters (Figure 20). The U.S. Environmental Protection Agency operates a national water quality data storage and retrieval system (STORET). Published and unpublished Lake St. Clair data from several Federal, state, provincial, and local agencies have been entered into this STORET for the period 1967-1982. Table 14 represents a retrieved STORET summary (mean values) for 22 parameters measured in the St. Clair River, Lake St. Clair, Detroit River, and western Lake Erie during this period.

Mudroch and Capobianco (1978) determined the geochemical composition of the surface sediments (0 to 20 cm) and the overlying marshwater in Big Point Marsh on the Ontario shore of Lake St. Clair (Tables 15 and 16). Mineralogically the sediments are composed of illite, quartz, calcite, dolomite, K-feldspars, plagioclose, and minor amounts of chlorite and kaolinite. The water can be characterized as hard with high levels of nutrients. The pH of the marsh sediment is about 7.0, while the overlying water ranges between 8.1 and 8.4.

Temperature

Two important features which determine the water temperature of Lake St. Clair are the lake's shallowness and the high flow rate from Lake Huron. Because of the shallow depth of Lake St. Clair, it warms quickly in the spring and cools rapidly in the fall. The lake is too shallow to stratify thermally; therefore the water is almost always isothermal from surface to bottom. The high inflow from the St. Clair River

Table 13. Lake St. Clair water quality measurements for 1973 growing season.[a]

	Open lake			Anchor Bay			Clinton River Mouth			L'Anse Creuse Bay		
Parameter	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Secchi depth (m)	1.9	1.6	2.2	2.0	1.3	1.7	2.0	1.4	2.3	0.6	0.9	1.2
Conductivity (umohs/cm)	184	203	202	181	213	205	183	214	210	340	273	274
Temperature °C	19.1	22.3	21.2	19.4	23.5	22.0	20.2	22.9	21.9	23.3	24.6	21.1
pH (units)	8.6	8.6	8.8	8.5	8.7	8.8	8.6	8.6	8.7	8.5	8.8	8.5
Dissolved oxygen (mg/l)	8.1	8.2	7.2	8.3	8.7	7.7	6.9	8.0	7.6	8.5	7.9	7.1
Suspended solids (mg/l)	7.3	11.6	11.8	4.0	12.0	15.0	4.3	6.9	12.0	35.7	11.7	26.3
Dissolved solids (mg/l)	127	129	--	127	120	--	127	124	--	218	153	--
Alkalinity (mg/l)	80	81	90	78	80	88	80	80	90	114	90	108
Hardness (mg/l)	--	--	95	--	--	95	--	--	96	--	--	119
Sodium (mg/l)	5.1	6.1	5.2	5.1	5.5	5.3	5.3	5.6	5.1	15.8	9.7	12.7
Magnesium (mg/l)	7.8	--	8.0	8.0	--	7.9	8.0	--	8.0	12.1	--	9.8
Calcium (mg/l)	--	26.1	24.9	--	26.0	25.0	--	26.9	25.3	--	31.0	31.7
Potassium (mg/l)	--	--	0.8	--	--	0.9	--	--	0.8	--	--	1.6
Sulfate (mg/l)	--	18.8	17.7	--	17.5	17.5	--	18.7	17.9	--	19.1	22.9
Phosphorus, total (µg/l)	29	60	15	<10	<10	<10	34	12	<10	276	100	210
Phosphorus, soluble (µg/l)	17	<10	<10	<10	<10	<10	18	<10	<10	160	44	133
Nitrate (µg/l)	277	295	203	260	235	225	275	240	195	470	212	365
Ammonia (µg/l)	30	29	10	10	25	15	32	31	<10	322	95	345
Organic nitrogen (µg/l)	383	330	331	265	285	285	404	371	150	862	590	491
Silica (mg/l)	--	1.48	2.25	--	2.05	2.35	--	2.34	2.34	--	2.77	3.40
Chlorophyll a (µg/l)	4.16	0.93	1.79	3.08	0.58	1.07	3.69	0.29	1.11	31.45	8.95	12.20

[a]Data source: Michigan Water Resources Commission (1975).

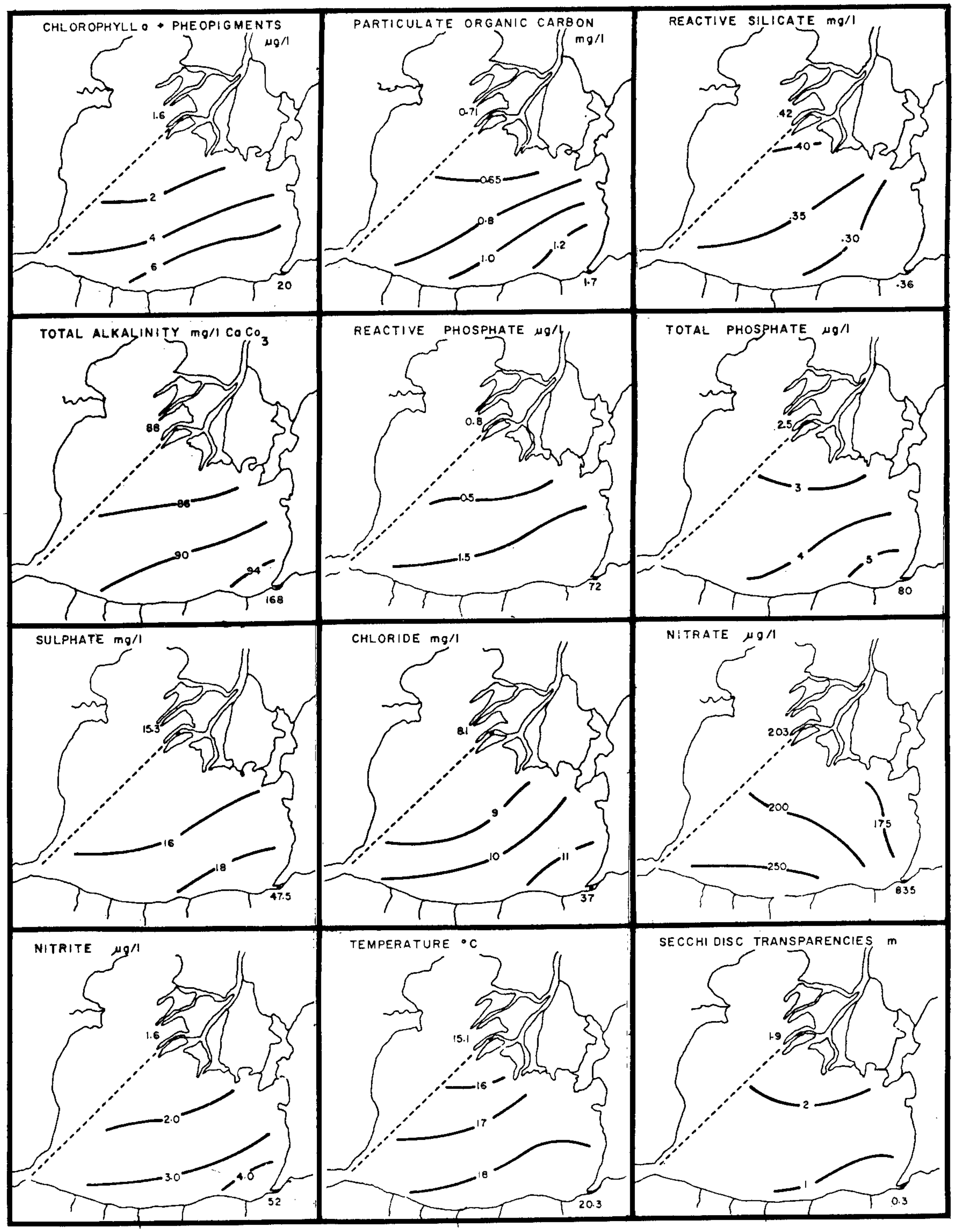

Figure 20. Mean water quality characteristics of Lake St. Clair from April through November 1971 (Leach 1972). Note increased concentrations near the southeast shore in the vicinity of the Thames River mouth.

Table 14. Chemical and physical characteristics of Lake St. Clair and adjacent waters (mean record 1967-1982).[a]

Parameter	Units	St. Clair[b] River	Lake St. Clair	Detroit River	Western Lake Erie
Temperature	^oC	11.8	18.9	14.6	17.3
Dissolved oxygen	mg/l	10.4	9.5	9.3	9.8
D.O. saturation	%	97.0	102.0	92.0	98.0
Conductivity (25°C)	umohs/cm	329.0	224.0	256.0	282.0
Dissolved solids	mg/l	143.0	135.0	140.0	194.0
Suspended solids	mg/l	21.6	12.1	15.4	19.9
Secchi depth	m	0.4	1.5	1.0	0.8
Alkalinity	mg/l	91.6	81.6	83.4	82.3
pH	units	8.1	8.3	8.0	8.4
Calcium, total	mg/l	51.2	29.1	29.8	34.4
Magnesium, total	mg/l	18.2	7.6	7.5	7.6
Potassium, total	mg/l	3.2	1.0	1.0	1.2
Sodium, total	mg/l	47.4	4.9	6.1	8.9
Chloride, total	mg/l	20.1	8.1	17.2	20.8
Sulfate, total	mg/l	16.6	16.7	16.1	32.7
Fluoride, total	mg/l	0.12	0.12	0.11	0.24
Silica, dissolved	µg/l	1.11	0.72	0.83	0.94
Ammonia, dissolved	µg/l	18.0	33.0	47.0	61.0
Nitrate + Nitrite, diss.	µg/l	290.0	295.0	300.0	325.0
Phosphorus, total	µg/l	62.7	44.5	70.1	78.7
Phosphorus, dissolved	µg/l	11.9	8.1	33.8	29.3
Chlorophyll a	µg/l	11.9	4.7	3.4	13.5

[a]Data source: U.S. Environmental Protection Agency, Large Lakes Station, Grosse Ile, Michigan, STORET Data System.

[b]Readings do not reflect mean concentration at the St. Clair River due to location of sampling stations near major outfalls.

(approximately 5,000 m^3/sec) quickly replaces the water in the lake with water from Lake Huron (in about 9 days). Thus, the temperature of Lake Huron has a strong influence on the temperature of Lake St. Clair. This is especially true in Anchor Bay and along the Michigan shore because most of the water from the St. Clair River enters the lake via the North Channel (33%) at the east side of the bay.

Like Lake Erie, highest temperatures are reached in August. On the Ontario shore, water temperatures average about 24°C in July and August. On the western side of the lake, which is influenced more by the cool water from Lake Huron, temperatures are usually 2 to 4°C lower. Temperatures are highest in the shallow coastal wetlands, reaching over 28°C. The typical summer thermocline of deeper lakes in the Great Lakes system is non-existent in Lake St. Clair.

In the fall, the lake is warmest on the western side, a reversal of the summer pattern. Water is coolest in the shallows near shore and warmest near the mouth of the St. Clair River. Normally Lake St. Clair is almost completely ice covered by mid-January. Ice break-up usually occurs in early March.

Transparency and Light Penetration

Mid-summer water transparency (Secchi disc) in Lake St. Clair normally ranges from 0.7 m along the Michigan shore to 2.6

Table 15. Geochemical composition of sediments in Big Point Marsh, Ontario, on Lake St. Clair.[a]

Parameter	Concentration (ppm)
SiO_2	49.4
Al_2O_3	8.0
Fe_2O_3	4.2
MgO	1.4
CaO (%)	6.0
Na_2O	0.42
K_2O	1.2
TiO_2	0.44
MnO	0.07
P_2O_5	0.37
Pb	63.7
Zn	93.7
Cr	24.9
Ni	21.8
Cd	1.3
Co	8.6
Cu	43.7
Organic C (%)	3.8

[a]Data source: Mudroch and Capobianco (1978).

km near the center of the lake to 0.6 m along the Ontario shore (Herdendorf 1970). In the nearshore regions the water color is brownish-green. Water in the vicinity of the navigation channel is a distinctive cloudy-green but near the center of the lake away from the channel is a clear-green.

Table 16. Chemical composition of water, Big Point Marsh, Ontario, Lake St. Clair.[a]

Parameter	Concentration Min. (mg/l)	Concentration Max. (mg/l)
Ammonia-Nitrogen	0.043	0.45
Nitrate-Nitrogen	0.017	0.49
Nitrogen, Kj	1.12	3.70
Phosphorus, total	0.02	0.13
Potassium	0.30	2.70
Calcium	45.0	66.0
Magnesium	9.5	13.0
Sodium	5.0	11.0
Alkalinity, total	92.0	115.0
	(μg/l)	(μg/l)
Lead	1	50
Zinc	1	54
Chromium	<1	1
Copper	<1	9
Cadmium	<1	1

[a]Data source: Mudroch and Capobianco (1978).

The minimum intensity of subsurface light that permits photosynthesis has been set at 1.0% of incident surface light (Cole 1983). The zone of a lake from the surface to a depth at which 99% of the surface light has been absorbed is known as the euphotic zone. Below this depth, primary productivity is considered nil. The relationship between Secchi disc transparency and the thickness of the euphotic zone provides a simple way to estimate the photosynthetically active region of a lake. A ratio of 3.0 to 3.5 has been empirically determined for this relationship, yielding a thickness of the euphotic zone ranging from about 2 m along the shores to over 9 m near the center of the lake.

Nutrients

Nitrogen, phosphorus, and silica are the primary limiting nutrients in Lake St. Clair. Bicarbonate alkalinity is in such

great abundance (>80 mg/l) that a source carbon for primary productivity is never lacking. Relatively high nitrate (>400 µg/l), phosphorus (>200 µg/l) and silica (>2 mg/l) in the nearshore waters of the wetland bays (Table 13) reflect high watershed inputs. Leach (1972) also found high nutrient loading from the Thames River (Table 17). The mid-lake lower concentrations reflect low nutrient loading from Lake Huron water. The mean Lake St. Clair concentrations of nutrients lie between values for the upper Great Lakes and those of western Lake Erie (Schelske and Roth 1973), yielding a mesotrophic classification for this lake.

On the basis of water chemistry, Leach (1980) identified two distinct water masses in Lake St. Clair: 1) a northwestern mass consisting primarily of Lake Huron water flowing from the main channels of the St. Clair River and 2) a southeastern mass of more stable water enriched by nutrient loadings from Ontario tributaries and shoreline urban development. The margins of the water masses shift according to the wind direction and speed, but the overall discreetness of the distribution is maintained during the ice-free periods of the year (April-December). A compression of the water quality characteristics of the two water masses for the period 1971-1975 is shown in Figure 21.

Dissolved Oxygen

Because thermal stratification does not occur, due to the lake's shallowness and rapid flow of the St. Clair River, dissolved oxygen concentrations are usually at saturation. In Bradley Marsh, north of the Thames River, Mudroch and Capobianco (1978) found that the temperature and dissolved oxygen saturation in marshwater during the growing season are inversely related (Figure 22), but the O_2 saturation did not fall below 75%. The coastal marshes are shallow and well mixed by wind, and consequently the water temperature is affected directly by air temperature. The diurnal temperature changes are large, for example in July 1976, they found marshwater temperature at 0600 hours to be 20°C and at 1500 hours, 27°C. These changes coupled with wind maintain high O_2 levels in the marshwater during the summer.

Organic Contaminants

The Michigan Water Resources Commission (1975) reported that

Table 17. Comparison of chemical characteristics of Lake St. Clair and associated waters.[a]

Parameter (units)	Mean Concentrations (April-November) Delta Channels	Lake St. Clair	Thames River
Chlorophyll *a* (µg/l)	1.2	3.4	13.0
Pheopigments (µg/l)	0.4	1.1	6.6
Part. org. carbon (mg/l)	0.7	0.9	1.7
Sol. react. phosphate (µg/l)	0.6	1.1	72
Total phosphate (µg/l)	2.5	4.0	80
Nitrate (µg/l)	178	202	835
Nitrite (µg/l)	1.6	2.7	52
Sol. react. silicate (mg/l)	0.3	0.3	0.4
Total alkalinity (mg/l)	87	89	168
Sulfate (mg/l)	15.3	16.8	47.5
Chloride (mg/l)	8.1	10.0	36.7

[a]Data source: Leach (1972).

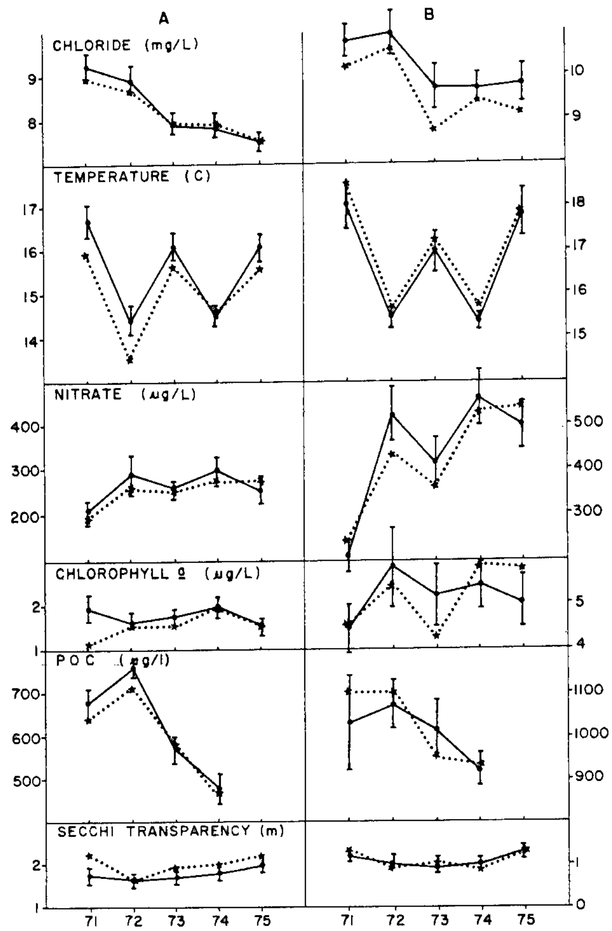

Figure 21. Characteristics of Lake Huron water mass (A) and Ontario nearshore water mass (B) in Lake St. Clair from 1971 to 1975 (Leach 1980). Solid line is mean water quality for each water mass and dashed line is prediction based on a central station in each water mass.

chlorinated hydrocarbon concentrations in sediments are low throughout the lake. Lindane, aldrin, endrin, heptachlor (detection limits 0.001 mg/kg), and chlorodane (detection limit 0.005 mg/kg) concentrations were below detection, and dieldrin (detection limit 0.001 mg/kg) was only detected at a few stations, then at maximum levels of only 0.006 mg/kg. DOE, TDE, and DDT (detection limit 0.002 mg/kg) were below detection at most stations, but high concentrations (0.039 mg/kg) were found in L'Anse Creuse Bay near the Clinton River spillway. PCB (detection limits 0.05 mg/kg) levels were below detection in most nearshore areas, but concentrations ranged from 0.50 to 1.10 mg/kg near the spillway, indicating that the Clinton River is an important source of PCB's.

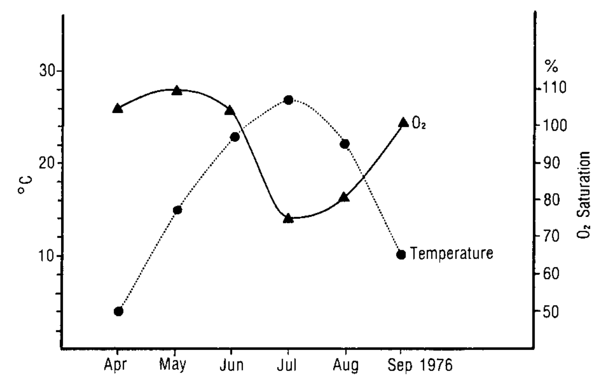

Figure 22. Temperature and dissolved oxygen relationship in a Lake St. Clair coastal wetland, near the mouth of the Thames River, Ontario (Mudroch and Capobianco 1978).

CHAPTER 3. BIOTIC ENVIRONMENT

3.1 PLANKTON

Phytoplankton and Sessile Algae

Planktonic and sessile algae, although not as important as macrophytes in the coastal marshes, are significant primary producers of organic matter in wetlands, converting the sun's energy into chemical compounds that in turn are used as food by animals and nonphotosynthetic micro-organisms. In the nearshore and open waters of Lake St. Clair, however, alga productivity dominates. Phytoplankton production and distribution are influenced by sunlight, temperature, nutrients, morphometry, water movements, grazing by zooplankton, and other factors. Many inorganic elements are required for algal cell growth, including nitrogen, phosphorus, potassium, calcium, and iron. Algae reproduce rapidly when phosphorus is added to the water, and continue to reproduce as more phosphorus is added. However, nitrogen and other nutrients must also be present if algal production is to continue. Recycling of nutrients within a marsh may be sufficient to promote algal blooms for several years after the initial loading (Sawyer 1954).

Pieters (1893) was the first botanist to describe the algae of Lake St. Clair, largely from the marshes of Anchor Bay. He noted that over 60 species of green algae, largely desmids, were associated with the vascular aquatic plants of the coastal wetlands. Winner et al. (1970) and the Michigan Water Resources Commission (1975) have made more recent studies of phytoplankton populations in Ontario and Michigan nearshore waters respectively. The results of these investigations are summarized in Appendix C. Diatoms are the most abundant forms of planktonic algae in the surface waters of the lake. *Asterionella*, *Nitzschia*, and *Synedra* are important genera throughout the water column. Filamentous forms such as *Cladophora*, are common where solid substrate is available, while *Spirogyra* is found in open waters of the marshes.

The distribution of the algal pigment, chlorophyll *a*, in Lake St. Clair can be used as an indicator of the relative abundance of phytoplankton. Leach (1972) found that starting at the delta channels, the concentrations of chlorophyll *a* and pheopigments increase toward the southeast (Figure 23), reaching the highest levels (20 µg/l) in the marshes at the mouth of the Thames River.

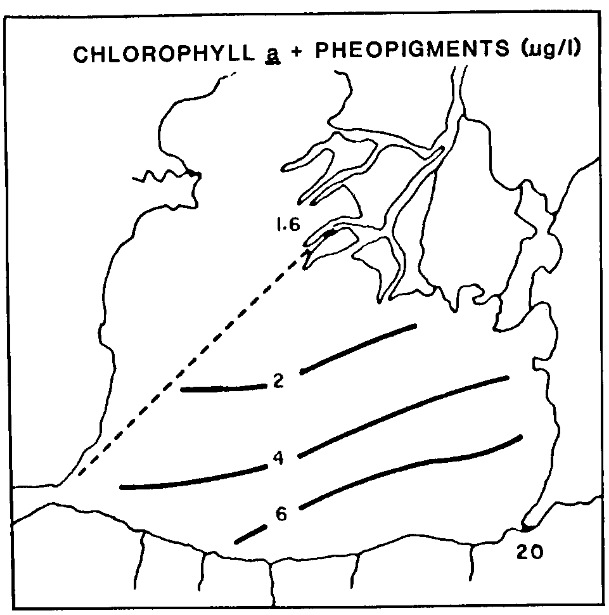

Figure 23. Concentration gradient of algal pigments across Lake St. Clair from the St. Clair Delta to the mouth of the Thames River (Leach 1972).

The strongest positive correlation was found during the spring plankton blooms.

Silica also has a strong relationship to the phytoplankton composition. Depletion of silica toward the end of the summer greatly reduces the percentage of diatoms in the phytoplankton community. In the southern portion of Lake St. Clair, diatom concentration falls from 95% of the total phytoplankton population in May to 10% of the population in July. Conversely, cyanophytas (blue-greens) increase from 0% of the total population in May up to 25% of the population in July (Leach 1972).

The term periphyton generally refers to microfloral growth, particularly sessile algae, on submerged substrate. Modifiers are normally used to indicate type of substrate: epipelic - growing on sediment; epilithic - growing on rock; epiphytic - growing on macrophytes; and epizooic - growing on animals (Wetzel 1975). The periphyton of western Lake Erie consists of predominantly littoral communities, most commonly associated with wetland vegetation. A greater number of species occurs in the littoral zone than in the limnetic zone of the lake due to the greater diversity of habitats available in the nearshore region. Although no detailed studies have been done in the Lake St. Clair wetlands, Millie (1979) examined the epiphytic diatom flora of aquatic macrophytes in marshes along the south shore of western Lake Erie. Three common species of wetland macrophytes were studied as hosts, narrow-leaved cattail (Typha angustifolia), white water lily (Nymphaea tuberosa), and swamp smartweed (Polygonum coccineum). Of the 247 diatom taxa identified (38 genera), 157 were new distributional records. Centric forms, such as Stephanodiscus subtilis, and keel-pennate forms, such as Nitzschia palea, were the most common taxa, but each marsh possessed a distinct flora and successional pattern. Millie attributed this heterogeneity to the diversity of littoral habitats in the marshes, particularly differences in chemical and physical factors. Because of the nearness and similarity of the Lake Erie marshes to the wetlands along the Ontario shore of Lake St. Clair, comparable periphyton communities would be expected for both lakes.

In Lawrence Lake, Michigan, Allen (1971) measured the annual net production of aquatic macrophytes and their attached algal forms. He found that the epiphytic algae were responsible for approximately 31% of the total littoral production in the lake. Brock (1970), working in the Everglades, observed that epiphytic algae, rather than macrophytes were responsible for the majority of the primary production of bladderwort (Utricularia sp.) communities. Diatoms were found to be the most abundant form of littoral periphyton, both in number and biomass, in several Ontario lakes (Stockner and Armstrong 1971). Likewise, it is anticipated that epiphytic diatoms are an important component of the energy base in Lake St. Clair marshes.

Zooplankton

By definition, plankton are floating organisms whose movements are more or less dependent on currents. However, some zooplankters exhibit active swimming movements that aid in maintaining vertical position. Zooplankters are diverse in their feeding habits. Herbivores graze on phytoplankton, periphyton, and macrophytes within the coastal marshes. Carnivores prey on attached protozoans and other zooplankters, while omnivores feed at all trophic levels. In turn, zooplankton are important fish and waterfowl food. Every fish species and many duck species utilizing the Lake St. Clair wetlands eat zooplankters during some portion of their life cycle.

The animal components of the wetland plankton (Figure 24) consist of three groups: protozoans, rotifers (Figure 25), and microcrustaceans (primarily cladocerans and copepods). Common zooplankters, including sessile or periphytic protozoans, occurring in Lake St. Clair wetlands are listed in Appendix D.

The first study of Lake St. Clair zooplankton, and one of the earliest limnological investigations in the Great Lakes, was organized by Reighard (1894) and included work by many of the leading

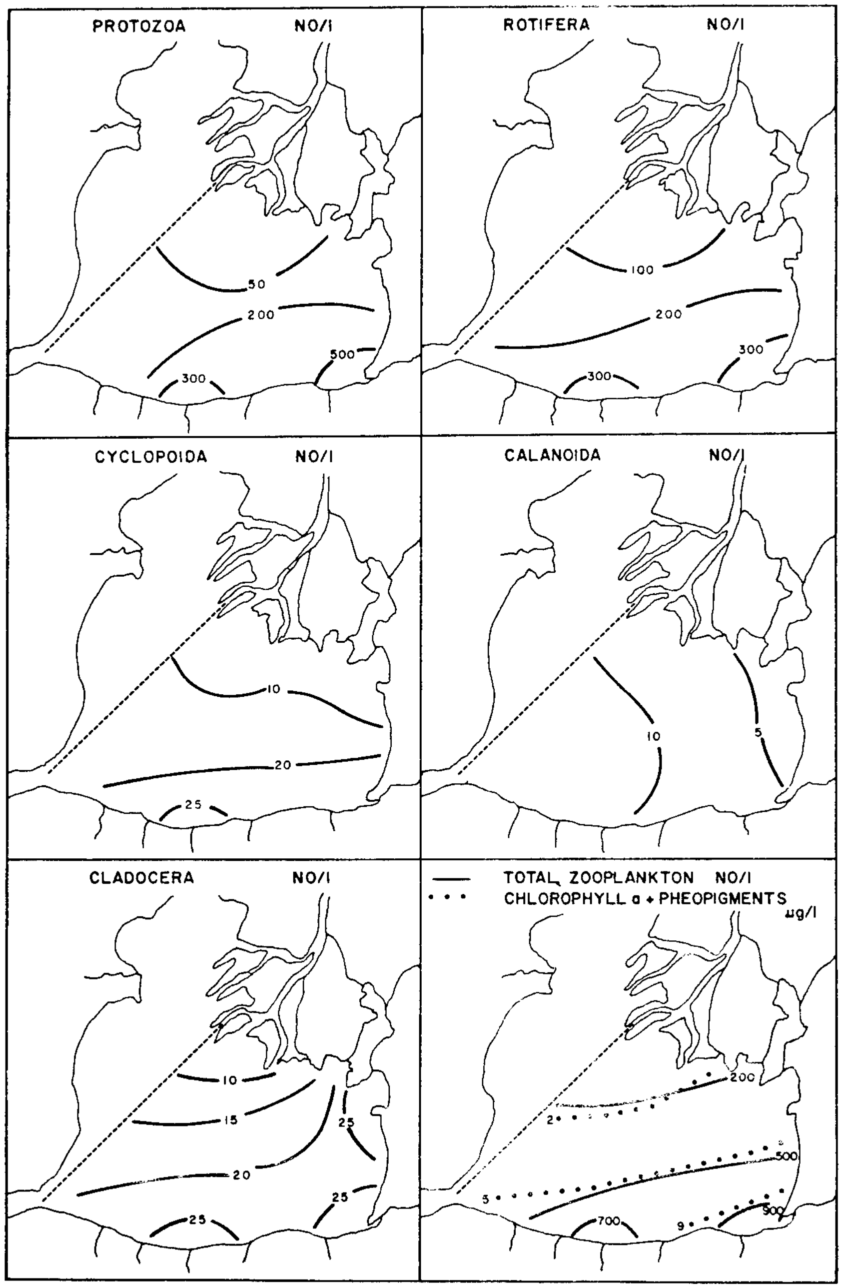

Figure 24. Mean distribution and concentrations of zooplankton groups in Lake St. Clair for April through November 1972 (Leach 1973). Note correlation between total zooplankton population and algal pigments.

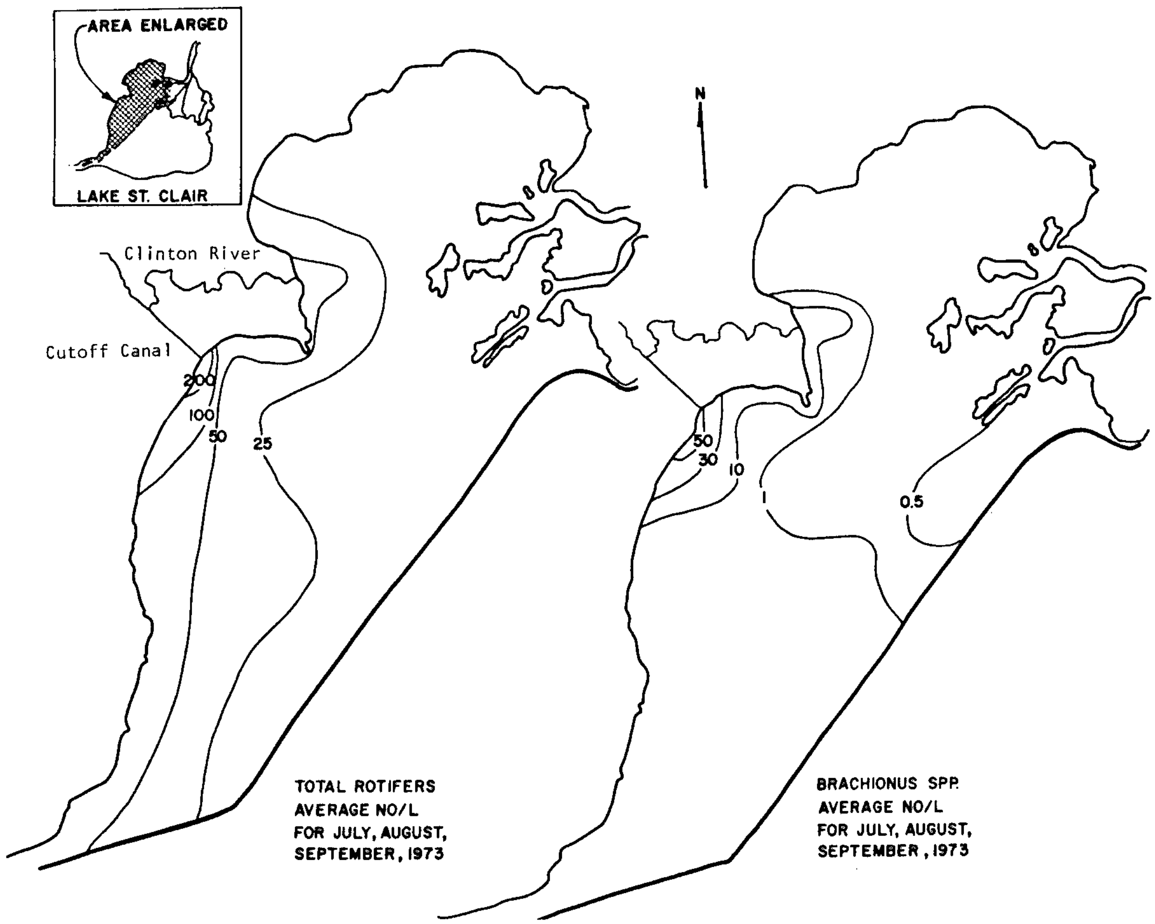

Figure 25. Distribution of total rotifers and most abundant genus, Brachionus, in Lake St. Clair during July-September 1973 (Bricker et al. 1976). Note high concentration in the vicinity of the Clinton River Cutoff Channel.

specialists of that period. Species lists of Protozoa (Smith 1894), planktonic Rotifera (Jennings 1894), Cladocera (Birge 1894), and Copepoda (Marsh 1895) were compiled from samples collected among aquatic plants in Anchor Bay and at other nearshore stations along the west shore of Lake St. Clair. Planktonic organisms remained neglected until Winner et al. (1970) obtained zooplankton data from two estuary mouths on the Canadian shore. Leach (1973) collected zooplankton samples from the South Channel of the St. Clair Delta, Mitchell Bay, the estuary mouth of the Thames River, and other nearshore and offshore stations on Lake St. Clair. Bricker et al. (1976) documented the zooplankton populations of Anchor Bay, the nearshore region in the vicinity of the Clinton River estuary, and offshore regions of Lake St. Clair. The results of these collections are included in Appendix D.

The distribution of zooplankton in Lake St. Clair is largely dependent on the prevailing currents of the lake. Other influences, such as temperature, algal abundance, and chemical characteristics also determine the concentrations of zooplankton. Because these factors vary greatly throughout the lake, the distributions of zooplankton also vary considerably in different portions of the lake (Bricker et al. 1976). A persistent eddy structure in the southeastern portion

of the lake (Figure 14) promotes entrainment of the waters and allows nutrient and algal levels to increase above other portions of the lake (Leach 1972). Because of the high phytoplankton levels in this area, the zooplankton biomass is greater here than in any other region. The rapid flow conditions of water through the delta and the Michigan portion of the lake inhibits any great concentration of zooplankton; therefore, the biomass is greater on the Ontario side (Figure 24). Despite rapid flow rates, zooplankton biomass is elevated near the Clinton River Cutoff Canal (Figure 25) due to nutrient loading from the watershed (Bricker et al. 1976).

Because of the rapid flushing rate of Lake St. Clair (9 days) and the dense submergent macrophyte populations competing for available nutrients, the total biomass of plankton in Lake St. Clair is low. Zooplankton that succeed the best in this environment are those that have a short life span and a fast turnover rate. For that reason, rotifers are the most abundant forms of zooplankton found. Mean numbers of rotifers ranged from approximately 62/l in July and 69/l in August down to 10/l in September (Leach 1973). These organisms are thirty times more abundant at the Clinton River Cutoff Canal (Bricker et al. 1976). Crustaceans have a consistently low abundance in the lake ranging from a high of around 6/l to a low of 0.3/l. As with rotifers, the peak abundance occurs in July and the low occurs in September. Cyclopoid and calanoid copepods, and cladocerans (water fleas) are the predominant microcrustaceans found in the lake (Figure 24). Protozoans vary in abundance but have the second highest occurrence following the rotifers. They compose an average of 37% of the total zooplankton community.

3.2 WETLAND VEGETATION

Although wetland communities exist in the St. Clair River (Figure 26), Clinton River, Marsac Point, Swan Creek, and St. Clair Delta complexes, only the latter area has been well studied. Therefore, the description of the plant communities

Figure 26. Ontario shoreline of St. Clair River at Cathcart Park (August 1984).

herein is based on the St. Clair Delta wetlands, particularly those on Dickinson Island. Important literature sources, by wetland area, are: St. John's Marsh (Roller 1976), Dickinson Island (Jaworski et al. 1979, 1981), Canadian side of the St. Clair Delta (Bayly 1975), and the entire delta complex (Jaworski and Raphael 1978; Raphael and Jaworski 1982). Lyon (1979) mapped the wetlands communities on the Michigan side of the St. Clair Delta using the wetlands classification of the U. S. Fish and Wildlife Service and a map scale of 1:24,000. Hayes (1964) surveyed the plant communities of a wet prairie on Harsens Island.

Several distinct environmental types, or plant zones, have been identified within the St. Clair Delta wetland complex located in northeastern Lake St. Clair. These zones are part of a vegetation continuum (Figure 27). For example, on the 11.3 km^2 Dickinson Island, the plant communities grade from cattail marsh along the southwest shore to upland hardwoods on the northeast point. Lake level fluctuations control the development and areal extent of the various zones (Jaworski and Raphael 1978). The important aquatic macrophytes of Lake St. Clair are listed in Appendix E, and distribution maps of several species are presented in Figure 28.

Coastal Embayments

This type includes plant communities such as those present in Goose Bay, Gooseneck Pond of Fisher Bay, and Little Muscamoot Bay. Species are largely submerged and emergent aquatic macrophytes. Habitats consist of low-wave energy lake bottoms and nearshore environments of bays where the water depths range from 0.3 to 1.5 m. Certain species, such as the cattails and the bulrushes can withstand moderate wave energy. Common vascular plants include the following species:

- *Vallisneria americana* (eel grass, wild celery)
- *Pontederia cordata* (pickerel weed)
- *Nuphar advena* (yellow water lily)
- *Polygonum amphibium* (water smartweed)
- *Myriophyllum spicatum* (Eurasian water-milfoil)
- *Typha* x *glauca* (hybrid cattail)
- *Scirpus acutus* (hard-stem bulrush)
- *Scirpus americanus* (three-square bulrush)
- *Potamogeton pectinatus* (sago pondweed)
- *Chara* sp. (muskgrass or stonewort).

Island Shorelines and Transgressive Beaches

Low, narrow beaches of fine sand and stands of emergent vegetation (Figure 29) are found on the Canadian side of the delta. The sand extends down less than 1 m and exhibits alternating layers of clean

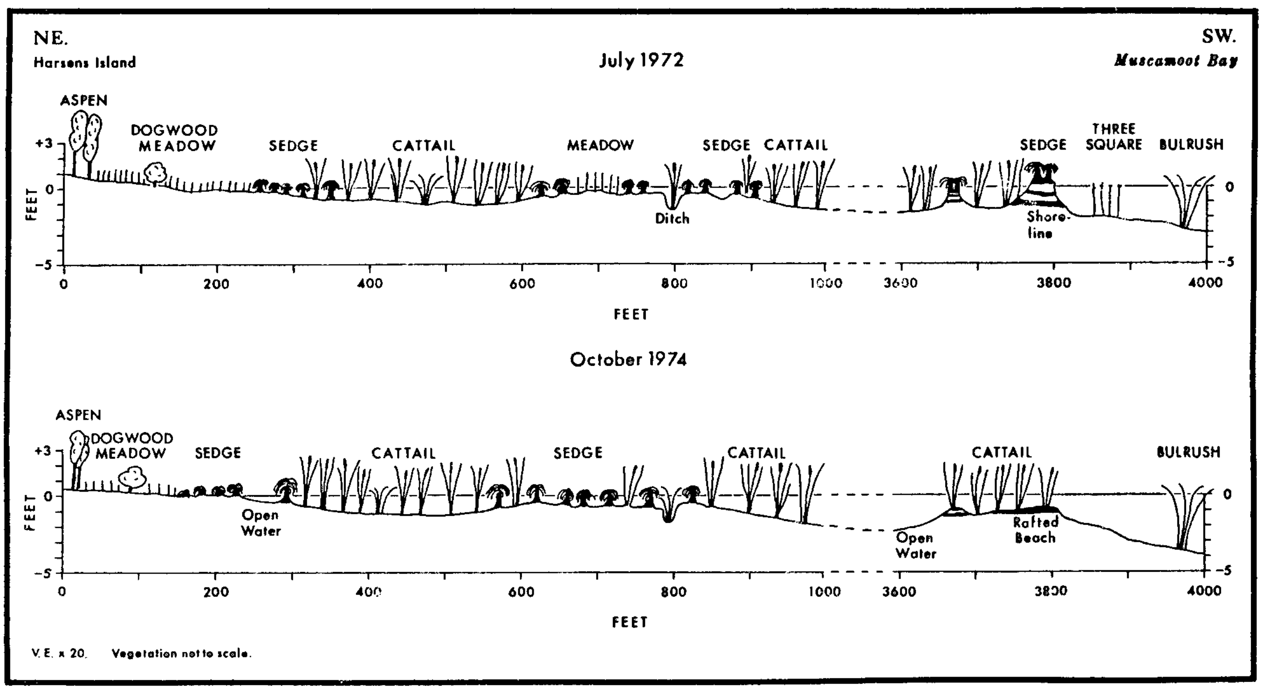

Figure 27. Vegetation transects on Harsens Island, St. Clair Delta, showing impact of rising water levels (Jaworski and Raphael 1976).

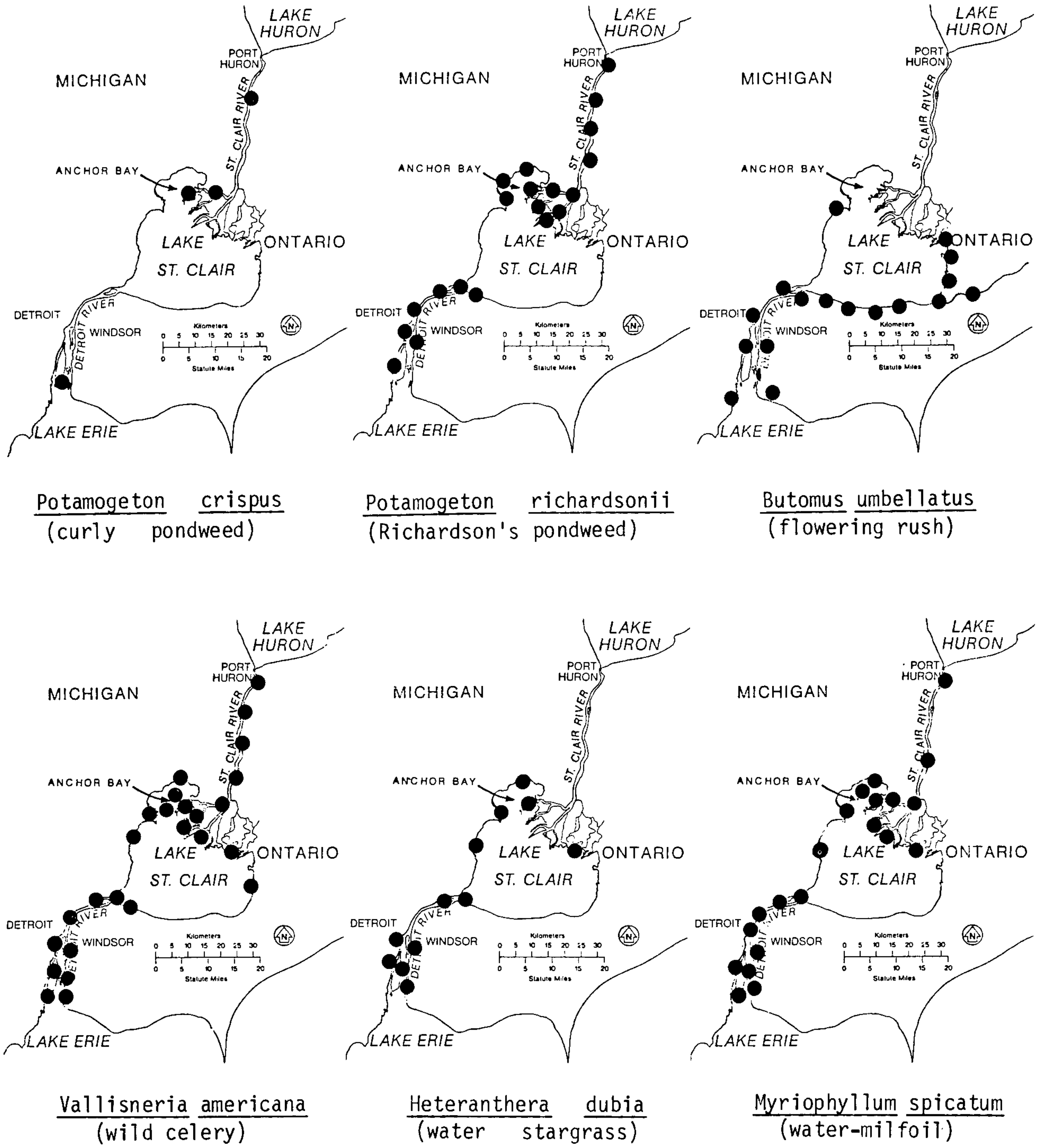

Figure 28. Distribution of six aquatic macrophytes in the St. Clair River-Lake St. Clair-Detroit River ecosystem (Schloesser and Manny 1982, unpublished data supplied by R. L. Stuckey).

Figure 29. Emergent stand of reed grass (Phragmites australis) along Chematogan Channel, Walpole Island, Ontario (August 1984).

sand and organic-rich sand or peat. Stranded or transgressive, beach ridges are low, sandy features on the delta islands that can be up to 100 m wide. Normally these ridges are only slightly above the water level. Characteristic vegetation of these sandy habitats includes the following vascular species:

Populus deltoides (eastern cottonwood)
Rhus typhina (staghorn sumac)
Salix spp. (willows)
Phalaris arundinacea (reed canary grass)
Calamagrostis canadensis (bluejoint grass)
Carex stricta (tussock sedge)
Impatiens capensis (touch-me-not, jewelweed)
Phragmites australis (reed grass)
Cirsium muticum (swamp thistle)
Urtica dioica (stinging nettle)
Convolvulus sepium (morning glory)
Polygonum convolvulus (black bindweed).

Bulrush and Open-Water Marshes

This marsh type is prevalent within abandoned channels and in cattail marshes where open water and sandy sediments occur. Bulrushes are also common in shallow water along the Lake St. Clair shore and in bays, as in Anchor Bay. Water depths range from 0.6 to 1.2 m. Representative plants include the following species:

Scirpus acutus (hard-stem bulrush)
Cephalanthus occidentalis (buttonbush)
Chara sp. (muskgrass or stonewort)
Various emergent and submergent species.

Cattail Marshes

These marshes are broad zones located on the lower portions of the delta islands where water depths exceed 15 cm. They are also found on inundated shoulders of river channels and bottoms of shallow ponds and bays. Pure colonies of cattails (Typha x glauca) are associated with peaty or clayey sediments (Figure 30). In small, shallow openings in the cattail marshes, duckweeds (Lemna minor and Spirodela polyrhiza), water-milfoils (Myriophyllum alterniflorum and M. spicatum), and bladderwort (Utricularia vulgaris) are abundant.

Sedge Marshes

This marsh type comprises a narrow zone between the cattail marsh and the grassy meadow or the dogwood shrub zones. Sedge marshes are also found along river channels, at the base of old shorelines now stranded in cattail marshes, and along the edge of eroding lake and bay shorelines. These marshes form on occasionally flooded wet sites where permanent water depths do not exceed 15 cm. Common species present include the following:

Calamagrostis canadensis (bluejoint grass)
Carex stricta (tussock sedge)
Carex lacustris (tussock sedge)
Carex lasiocarpa (tussock sedge)
Carex lanuginosa (tussock sedge)
Carex sartwellii (tussock sedge)

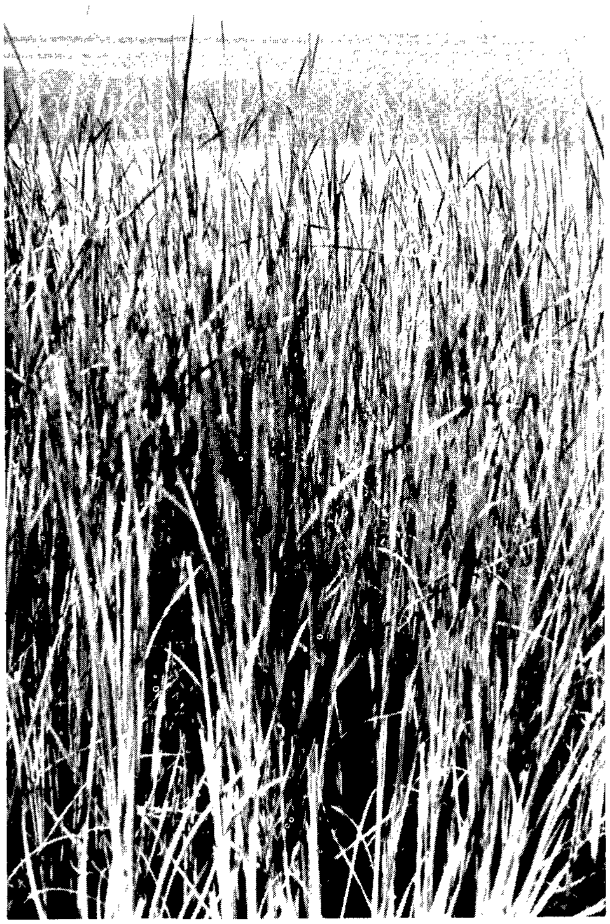

Figure 30. Emergent stands of narrow-leaved cattail (Typha angustifolia) on Little Muscamoot Bay, Harsens Island, Michigan (August 1984).

Symphytum officinales (common comfrey)
Solanum dulcamara (nightshade).

Canals and Ponds

These habitats include artificial canals and openings in the marshes (ponds). Water depths are generally shallow, 0.3 to 0.6 m, and sediments are usually clayey or organic. Communities can be quite variable. Typical species include the following:

Nuphar advena (yellow water lily)
Nymphaea tuberosa (white water lily)
Lemna minor (duckweed)
Pontederia cordata (pickerel weed)
Elodea canadensis (waterweed)
Polygonum amphibium (water smartweed)
Potamogeton crispus (curly pondweed)
Potamogeton spp. (pondweeds)
Cephalanthus occidentalis (buttonbush)
Chara sp. (muskgrass or stonewort)
Cladophora sp. (filamentous green algae).

Abandoned Channels

Abandoned distributary channels in the delta are generally shallow, less than 1 m deep, and have silty or peaty sediments. The variable plant communities include the following species:

Nuphar advena (yellow water lily)
Nymphaea tuberosa (white water lily)
Myriophyllum alterniflorum (little water-milfoil)
Sagittaria latifolia (common arrowhead)
Scirpus acutus (hard-stem bulrush)
Scirpus americanus (three-square bulrush)
Cephalanthus occidentalis (buttonbush).

Wet Meadows

This type is a zone of transition vegetation or ecotone, between the sedge marshes and the hardwood community. This zone lies slightly above the water table and is infrequently flooded. The communities consist of a mixture of grasses, herbs and shrubs, and water-tolerant trees, including the following species:

Populus tremuloides (quaking aspen)
Fraxinus pennsylvanica (red ash)
Cornus stolonifera (red osier dogwood)
Rosa palustris (swamp rose)
Solidago spp. (goldenrods)
Calamagrostis canadensis (bluejoint grass)
Poa palustris (fowl meadow grass)
Leersia oryzoides (rice cutgrass)
Glyceria canadensis (rattlesnake grass)
Panicum sp. (panic grass)

Carex stricta (tussock sedge)
Asclepias incarnata (swamp milkweed)
Juncus effusus (soft rush)
Dryopteris thelypteris (marsh fern)
Potentilla anserina (silverweed).

Shrub Ecotones

This type also represents a transition into upland hardwood vegetation. The depth to the water table is normally 0.5 to 1.0 m in this zone. Communities are mixed shrubs, water-tolerant trees, and some understory plants typical of the meadows. Prominent plants include the following species:

Populus deltoides (eastern cottonwood)
Populus tremuloides (quaking aspen)
Fraximus pennsylvanica (red ash)
Cornus stolonifera (red osier dogwood)
Cornus racemosa (gray dogwood)
Vitis palmata (wild grape)
Crataegus sp. (hawthorn).

During low-water periods, these shrubs and swamp trees invade the sedge marshes. However, during high water conditions, as in the 1970s, flooding and die back of woody plants in the shrub zone are common.

Deciduous Hardwoods

Stands of oak-ash hardwoods occur in the upper portion of Dickinson, Harsens, St. Anne, Squirrel, and Walpole islands at elevations ranging from 1 to 3 m above mean lake level. The major species of these stands are *Fraxinus pennsylvanica* (red ash) and *Quercus bicolor* (swamp white oak). Associated hardwoods occurring in this type include the following species:

Quercus palustris (pin oak)
Quercus macrocarpa (burr oak)
Acer saccharinum (silver maple)
Ulmus americana (American elm)
Carya ovata (shagbark hickory)
Populus deltoides (eastern cottonwood).

Distribution of the Wetland Communities

The wetland plant communities of the St. Clair Delta occur in broad, arcuate zones which extend from the vicinity of Algonac, Michigan, southward into Lake St. Clair (Figure 31). In spite of extensive cultural modifications, sufficient natural wetland vegetation remains to reconstruct the community zonation. On the various islands of the delta, five major macrophyte communities can be mapped. These communities, from the driest to the wettest habitats, include: oak-ash hardwoods, dogwood meadow, sedge marsh, cattail marsh, and bulrush marsh. Other identifiable communities which are limited in extent include: canal-pond-abandoned channel, lakeshore and bay bottom, and reed grass communities.

Lakeward of the hardwoods is a complex of communities referred to as the dogwood meadow. This vegetation zone occurs as a transition zone between the hardwood forest and the wetter sedge marsh. It appears that periodic high lake level and human disturbance (such as burning and mowing) prevent woody species from dominating this zone. Major plant species herein are bluejoint grass (*Calamagrostis canadensis*), soft rush (*Juncus effusus*), gray dogwood, red osier dogwood, and quaking aspen.

The sedge marsh forms a narrow zone between the dogwood meadow and the cattail marsh, as well as along eroding lake and bay shorelines, particularly on the Michigan side of the delta. This community also occurs along lower distributary channels and on old shorelines. The sedge marsh is associated with the alkaline, inorganic soils which are either saturated or occasionally flooded. However, permanent inundation of the sedge tussocks results in dieback of the sedges. Major plant species are sedges of the genus *Carex* and bluejoint grass. *Carex stricta* is particularly abundant on Dickinson Island, whereas *C. lacustris* is common on Walpole Island.

Located on the lakeward margin of the delta, where water depths exceed 15 to 30 cm, is the broad cattail marsh zone. Zones of cattail also occur on inundated shoulders of the river channels, on lower ends of distributary channels, and on crevasses. Pure stands of cattail are associated with peaty or clayey sediments. The hybrid cattail (*Typha* x *glauca*), which attains 2 to 3 m in height and grows in

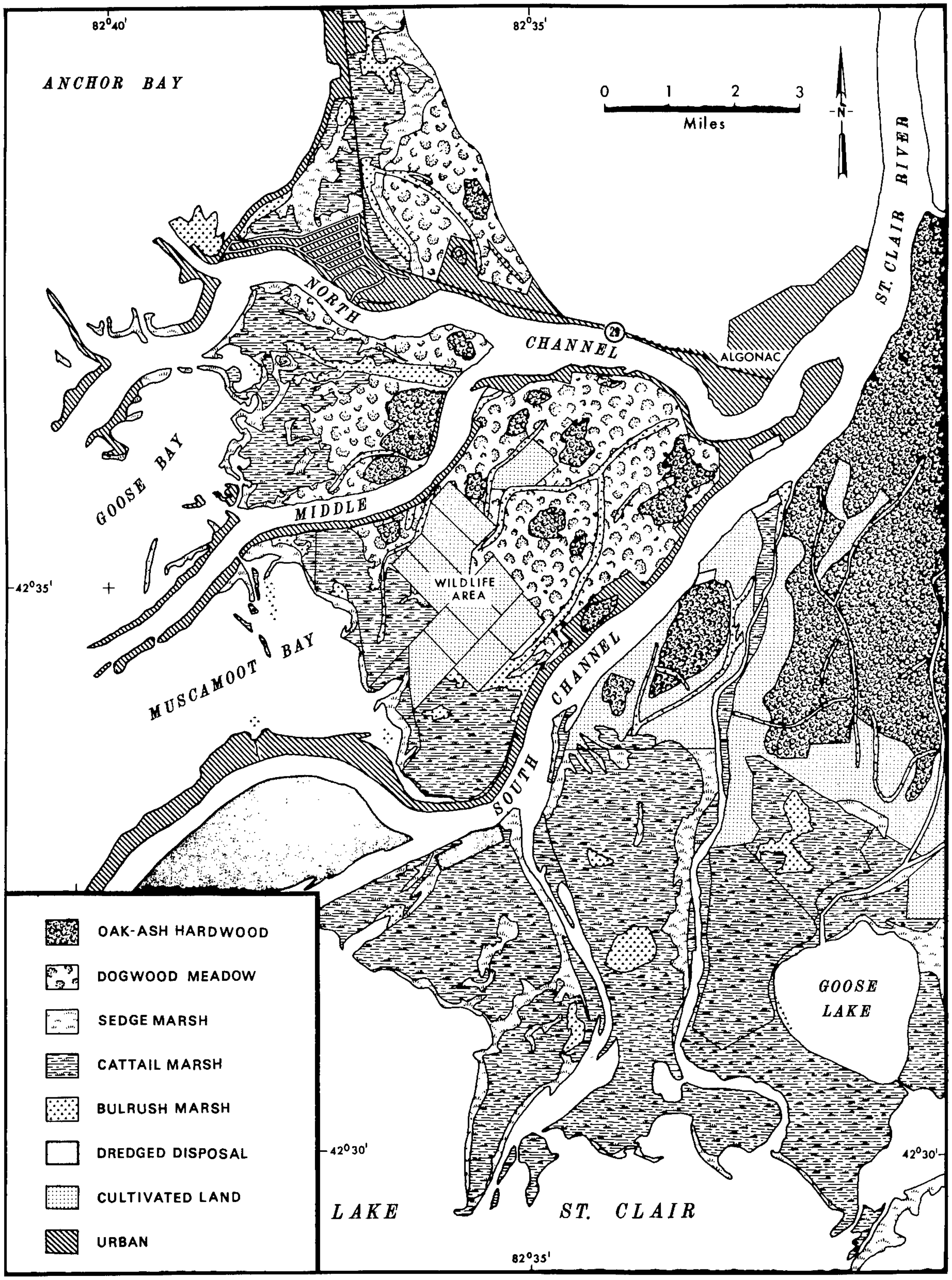

Figure 31. Wetland plant communities of the St. Clair Delta (Raphael and Jaworski 1982).

circular colonies, is the dominant species. Some narrow-leaved (T. angustifolia) and broad-leaved cattails (T. latifolia) can also be identified.

The bulrush marsh is found in abandoned river channels, in large open-water areas of the cattail marsh, and on sand bars in low-wave energy areas of Lake St. Clair and Anchor Bay. Colonies of bulrush are associated with sandy substrates and water depth of 0.5 to 1.25 m. The principal species of the marsh is hard-stem bulrush. Buttonbush is associated with the bulrush community in abandoned distributary channels where some water flow occurs.

In canals, abandoned river channels, marsh openings, and other stagnant water environments, a variety of floating and submersed aquatic communities occur. Water depths range from 0.24 to 1.0 m and water circulation is minimal except for wind-driven currents. Organic substrates are common along with turbidity due to humic acids and suspended particulate organic matter. Whereas species diversity is the rule, abundant plant species include duckweeds, pickerel weed, waterweed, water-milfoil, and water smartweed. Other associated species are white water lily (Nymphaea ordorata), yellow water lily (Nuphar advena), slender pondweed (Potamogeton pusillus) as well as green algae (Cladophora sp.).

Lake and bay-bottom communities occur along low wave energy bottoms and nearshore environments such as Little Muscamoot Bay. Water depths generally range between 0.3 and 2.0 m. Major species in this zone include wild celery, muskgrass or stonewort (Chara sp.), and flexed naiad. Brown (1983) reported the dominance of Chara, along with pondweeds, Eurasian water-milfoil, waterweed, and various emergents growing about Sand Island in Anchor Bay. Because of higher wave energy, lake and bay-bottom communities are less widespread on the Canadian side of the delta. In Lake St. Clair, Schloesser and Manny (1982) found very few macrophytes, which excludes Chara, beyond 1.25 km from shore.

Although conspicuous where present, the reed grass community is of insufficient distribution to map in the St. Clair Delta. Dense colonies of reed grass (Phragmites australis), usually less than 0.5 hectares in extent, are located in scattered patches on the drowned shoulders and natural levees of North, Middle, and South channels.

Wetland vegetation is not static from year to year (Section 4.3) . Dynamic change occurred in the plant communities during the interim 1964 and 1975 as water levels in Lake St. Clair fluctuated from very low levels to extreme high water conditions. Dickinson Island, which has a full complement of wetland zones, and except for the dredged material disposed in the early 1970s, had little development (Figures 32 and 33). In particular, large shifts occurred among the bulrush-submersed communities and the emergent sedges and cattails.

Endangered Plant Species

A literature search by Herdendorf et al. (1981c) revealed no plant species in the St. Clair Delta complex which appeared on Federal or State lists of endangered species. However, there is a very small patch of the rare plant, wild rice (Zizania aquatica,) located on lower Harsens Island. Moreover, Wagner (1977) reported the following threatened vascular plant species (Michigan) for Harsens Island: marsh sedge (Fimbristylis puberula), prairie fringed orchid (Habenaria leucophaea), Hill's thistle (Cirsium hillii), panic grass (Panicum leibergii), and sand grass (Triplasis purpurea).

3.3 INVERTEBRATES

St. Clair River-Lake St. Clair Ecosystem

In 1976 and 1977, the U. S. Fish and Wildlife Service (Hiltunen 1980; Hiltunen and Manny 1982) conducted surveys of the macrozoobenthos of the lower St. Clair River and Lake St. Clair. These surveys indicated that the St. Clair River and Delta support a diverse and abundant macrozoobenthos. The number of taxa and density found in the river system was

significantly greater than that found in Anchor Bay or the open portions of Lake St. Clair (Table 18).

In the St. Clair River and Delta, oligochaete worms are the most abundant macrozoobenthos (55%). Sixteen species are common, with the tubificid genera Peloscolex, Aulodrilus, and Potamothrix and the naidid genera Wapsa and Chaetogaster dominating. Dipteran larvae are the second most abundant group (26%). By number, the chironomids compose 95% of the dipterans. Crustaceans are among the less abundant forms and are represented by the amphipods of the four genera, Gammarus, Hyalella, Crangonyx, and Pontoporeia. The first three are permanent residents of the river wetlands; the fourth populates the deep waters of the Great Lakes and is probably transient from Lake Huron. The insect orders, Trichoptera and Ephemeroptera together compose only 1% to 2% of the total number of macrobenthos. Caddisflies are not as numerous as the mayflies, but are represented by a greater number of genera. The mayflies are largely Hexagenia (90%). Although the density of mayflies and caddisflies is low, these organisms are a significant part of total fauna because the biomass of their populations is greater than that of other insect groups (Hiltunen 1980).

The richness of the benthic fauna of Lake St. Clair is evident in the high diversity of taxa present in the wetlands of Anchor Bay and elsewhere in the lake (Table 18). The moderate abundance of oligochaetes as compared to other groups indicates the quality of the benthic environment is high. Hiltunen and Manny (1982) found the mean percent composition of the pollution-tolerant oligochaetes ranged from 25% in Anchor Bay to 49% elsewhere in Lake St. Clair. The values are far below the standard of 60% oligochaetes in polluted environments proposed by Goodnight and Whitley (1960). The presence of pollution-intolerant Ephemeroptera and Trichoptera in substantial numbers (300/m^2) at a nearshore station in Anchor Bay) supports the conclusion that the benthic environment of Lake St. Clair is not severely impaired by pollution (Hiltunen and Manny 1982).

Macrozoobenthos constitutes an important source of food for fish and waterfowl in the Lake St. Clair-St. Clair River wetlands. Price (1963), working in western Lake Erie, showed that rainbow smelt, alewives, gizzard shad, spottail shiners, trout-perch, yellow perch, channel catfish, white bass, and walleye feed heavily at different life stages on oligochaetes, leeches, cladocera, ostracods, amphipods, mayflies, caddisflies, midges, snails, and bivalves. Although little published work exists on the food habits of St. Clair River fishes, the aforementioned fish species and the invertebrates that they feed upon are all abundant in Lake St. Clair and the St. Clair River (Hiltunen 1980). Dawson (1975) has observed that many of the macrozoobenthos reported for Anchor Bay are also important sources of food for waterfowl inhabiting that bay. A list of the important benthic invertebrate species of the St. Clair River-Lake St. Clair ecosystem is presented in Appendix F.

Molluscan Fauna

During four different stages of the Pleistocene Epoch, which itself lasted from about one million to about ten thousand years ago, the Lake St. Clair basin was covered with glacial ice. Within the glaciated region all benthic organisms were destroyed, but each time the ice receded they reinvaded the previously ice-covered region. The Pleistocene mollusks of the interglacial lakes and their paleoecology are well documented by La Rocque (1966). Many species, particularly the unionid bivalves and the large prosobranch snails, require a continuous waterway for migration. Glochidia may be carried over long distances while attached to their fish host. The rich molluscan fauna of the Lake St. Clair region was largely repopulated from the Ohio-Mississippi system when glacial meltwaters in this region flowed south. Additionally, Clarke (1981) speculated that most small snails (pulmanates) and small clams (sphaeriids) are carried about imbedded in the feathers of water birds, in mud attached to their feet or clamped to the appendages of large, flying aquatic insects. Appendix G provides a listing of the mollusks

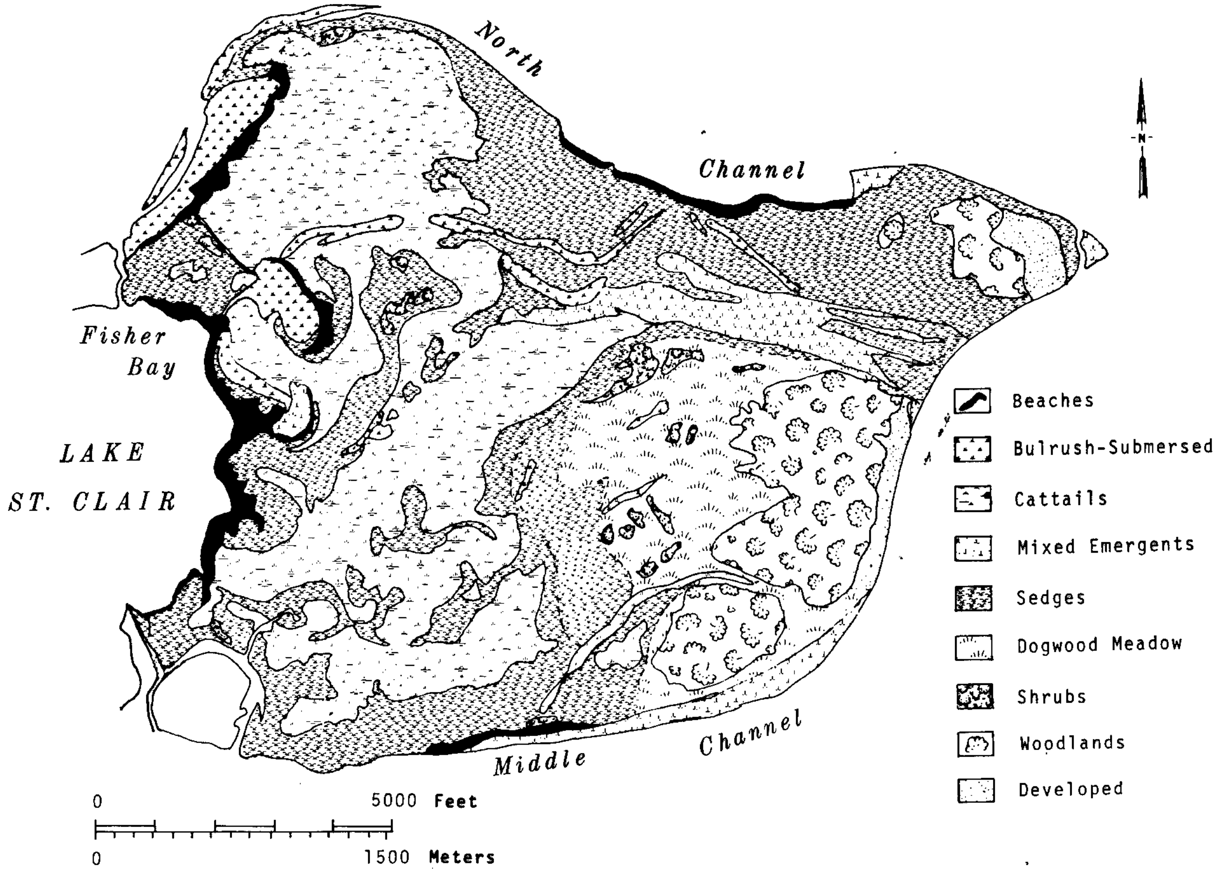

Figure 32. Wetland vegetation on Dickinson Island in 1964.

associated with the coastal wetlands and nearshore waters. Appendix H contains information on the habitat preference of these species.

Gastropods. Well-vegetated portions of unpolluted embayments, marshes, beach ponds, and sluggish tributary mouths are the most productive localities for freshwater snails in Lake St. Clair. They live on submerged vegetation, on rocks and on the bottom at the water's edge and out to a depth of several meters. Two subclasses, Prosobranchia and Pulmonata, are well represented in Lake St. Clair coastal marshes. The former group is characterized by internal respiratory gills (ctenidia), or as in Valvata, external gills, and an operculum used to seal the shell aperature. The latter group does not have gills, but obtains oxygen through a "lung-like" pulmonary cavity. Pulmonate snails, which have descended from land snails, must come to the surface periodically for air.

Most aquatic snails are vegetarians. The veneer of living algae which covers most submerged surfaces is their chief source of food, but dead plant and animal material is frequently ingested. Dissolved oxygen is an important limiting factor; most gilled species require high concentrations, with limpets such as Ferrissia being found only where the water remains near saturation (Pennak 1978). However, Campeloma decisum, and Amnicola limosa have been collected in water with less than 2 ppm oxygen (Harman 1974). The concentration of dissolved solids in Lake St. Clair, particularly bicarbonate alkalinity at over 80 mg/l, provides adequate essential materials for shell construction. Appendix H shows the habitat preferences for the 47 species of gastropods which have been reported for the coastal marshes and nearshore waters.

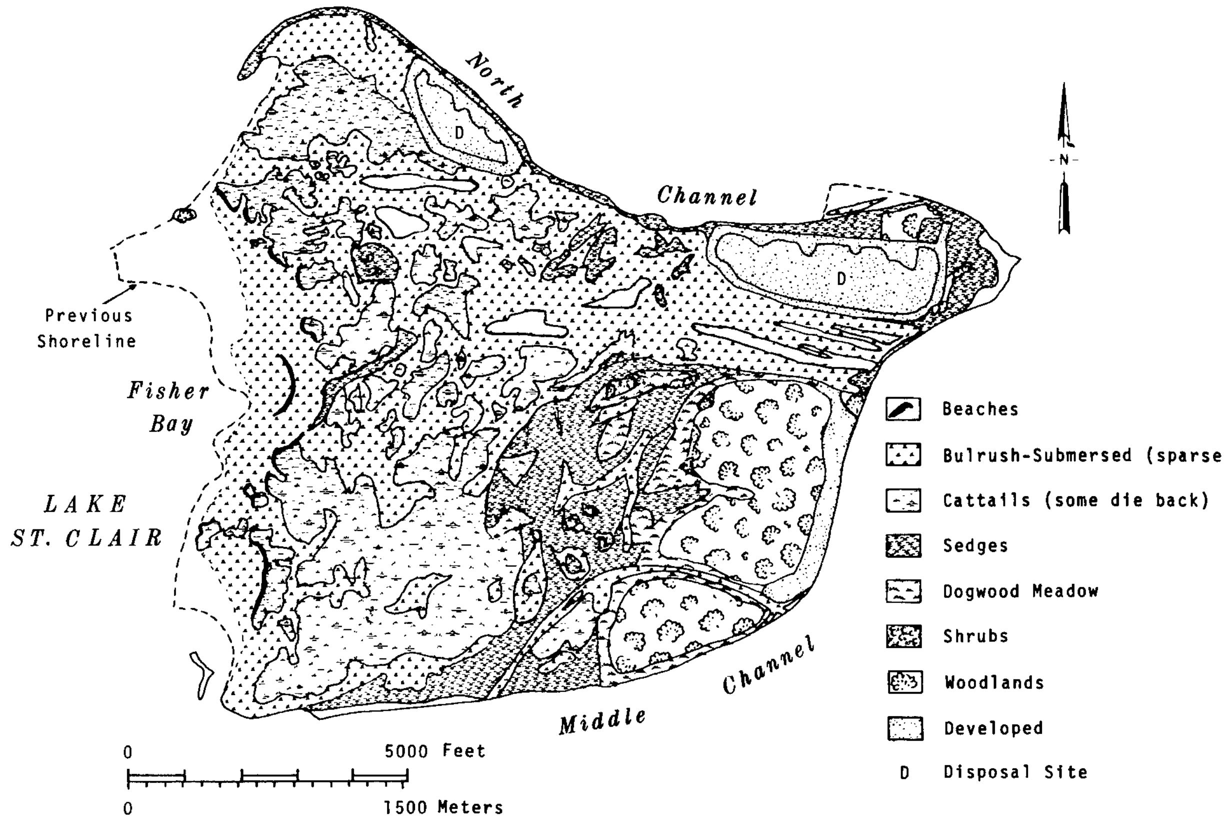

Figure 33. Wetland vegetation on Dickinson Island in 1975. Previous shoreline refers to 1964 shore shown in Figure 32.

Pelecypods. The bivalved molluscan fauna of Lake St. Clair consists of three families. The majority of the species belong to the Unionidae (freshwater mussels or naiades) and Sphaeriidae (fingernail clams). The third family, Corbiculidae (little basket clams), is represented by an introduced Asiatic species. Bivalves are most abundant nearshore, especially in water less than 2 m deep. Stable gravel and sand substrates with a good current support the largest populations. Commonly mussels inhabit substrates free of rooted vegetation, but there are numerous exceptions, including *Anodonta grandis* and *Quadrula quadrula*.

Stomach contents of unionid mussels are commonly mud, desmids, diatoms, and other unicellular algae, protozoans, rotifers, flagellates, and detritus. The largest populations of mussels develop below areas where disintegration of rich vegetation is occurring (Churchill and Lewis 1924).

The female pocket-book mussel (*Lampsilis ventricosa*) is capable of extending and pulsating the posterior edge of the mantle in such a way that it resembles an injured minnow (Clarke 1981). This activity attracts fish such as bluegill, white crappie, smallmouth bass, and yellow perch, and increases the opportunities for juvenile mussels (glochidia) to attach themselves to a fish after they have been ejected from the parent. The larvae are released by the parent when its light sensitive spots are stimulated, for example, by the shadow of a passing fish. Several unionid bivalves possess special mantle structures adapted to lure fish into their vicinity. The glochidia of each species of freshwater mussel (corresponds to veliger larvae of marine bivalves) must attach to the gills

Table 18. Macrozoobenthos of Lake St. Clair and the lower St. Clair River and Delta (1977).[a]

Major taxa	Open lake Composition (%)	Open lake Density (no./m2)	Anchor Bay Composition (%)	Anchor Bay Density (no./m2)	River and delta Composition (%)	River and delta Density (no./m2)
Nemertinea	-[b]	-	+	+	0.1	19
Nematoda	11.4	511	9.7	795	3.4	450
Hirundinea	+	+	+	+	0.2	28
Oligochaeta	40.8	1,826	28.8	2,350	52.7	6,979
Polychaeta	19.5	874	7.7	631	+	+
Amphipoda	4.1	182	11.8	967	5.1	674
Isopoda	0.3	12	6.8	555	0.4	50
Diptera	8.8	395	12.5	1,023	26.3	3,481
Ephemeroptera	2.6	118	1.9	151	0.8	100
Coleoptra	-	-	+	+	0.1	15
Lepidoptera	+	+	+	+	0.7	91
Trichoptera	+	+	+	+	0.2	33
Hydracarina	-	-	-	-	0.3	38
Gastropoda	1.8	82	11.2	917	6.7	883
Pelecypoda	7.9	355	3.4	276	3.0	402
Totals	97.2	4,355	93.8	7,665	100.0	13,243

[a]Data sources: Hiltunen (1980), Hiltunen and Manny (1982).

[b]- Absent
+ Present but not enumerated.

and fins of a particular fish species or small group of species (Table 19) before further development can take place. Most glochidia never accomplish this, but those that do succeed remain attached for a few weeks as they metamorphose into tiny mussels. The young mussels then drop from the fish to take up an independent life on the lake bottom, moving about and siphoning water for respiration and to obtain plankton as a source of nourishment. Appendix H indicates the habitat preferences of the 64 species of pelecypods which have been reported for coastal marshes and nearshore waters.

3.4 FISH

Lake St. Clair, along with the St. Clair River and the Detroit River, forms the connecting waterway between Lake Huron and Lake Erie, and is therefore an important fish conduit. The bays and wetlands of Lake St. Clair, especially in the St. Clair Delta area at the mouth of the St. Clair River, are important spawning and nursery areas for many species that support major fisheries in Lake St. Clair as well as Lake Huron and Lake Erie (Johnston 1977; Goodyear et al. 1982a,b,c; Hatcher and Nester 1983). Studies conducted at a number of widely separated sites in the Great Lakes indicate that the nearshore waters are spawning and nursery grounds for most fishes (Boreman 1976). More than 70 species of fish have been recorded as residents, or migrants, in Lake St. Clair; of these, 48 species are dependent on or known to use the marshes and shallow areas of the lake (Appendix I).

Although many species of fish utilize coastal wetlands, comparatively few

Table 19. Lake St. Clair unionid bivalves and their glochidial host fish.[a]

	Unionid Bivalves[c]															
Fish hosts[b]	AMB	FUS	QUA	ELL	ALA	LAS	SIM	ANO	STR	TRU	PRO	CAR	LEP	ACT	LIG	LAM
Northern pike	X															
Carp						X		X								
Golden shiner								X								
Creek chub								X	X							
White sucker					X											
N hog sucker					X											
N Sh redhorse					X											
Bl bullhead			X													
Ye bullhead								X								
Br bullhead			X													
Ch catfish	X		X													
Bk stickleback								X								
White bass	X							X						X		X
Rock bass	X				X			X						X		X
Gr sunfish	X					X		X				X		X		
Pumpkinseed	X															
Or-sp sunfish												X				
Bluegill	X	X						X				X		X	X	X
Sm bass														X		X
Lm bass	X					X		X			X			X	X	X
Wh crappie	X	X	X	X		X		X				X		X	X	X
Bl crappie	X	X		X				X						X		X
Iowa darter								X								
Johnny darter					X			X								
Ye perch				X				X						X		X
Walleye																X
Freshwater drum								X		X	X		X			
Mottled sculpin					X											
Mudpuppy (amphibian)							X									

[a]Data sources: Fuller (1974), Clarke (1981)

[b]N- northern
Sh- shorthead
Bl-black
Ye-yellow
Br-brook
Gr-green
Or-sp-orange-spotted
Sm-smallmouth
Lm-largemouth
Wh-white

[c]AMB - _Amblema plicata_
FUS - _Fusconaia flava_
QUA - _Quadrula quadrula_ and _Q. pustulosa_
ELL - _Elliptio dilatata_
ALA - _Alasmidonta viridis_ and _A. Marginata_
LAS - _Lasmigona complanata_ and _L. costata_
SIM - _Simpsoniconcha ambigua_
ANO - _Anodonta grandis grandis_ and _A. imbecilis_
STR - _Strophitus undulatus_
TRU - _Truncilla donaciformis_ and _T. truncata_
PRO - _Proptera alata_
CAR - _Carunculina parva_
LEP - _Leptodea fragilis_
ACT - _Actinonaias carinata_
LIG - _Ligumia recta_
LAM - _Lampsilis radiata_ and _L. ventricosa_

species are strongly dependent on aquatic vegetation for spawning, feeding, or cover. The more common wetland-dependent species found in Lake St. Clair and occurring frequently in the coastal wetlands include longnose gar (Lepisosteus osseus), bowfin (Amia calva), northern pike (Esox lucius), grass pickerel (Esox americanus), central mudminnow (Umbra limi), golden shiner (Notemigonus crysoleucas), blacknose shiner (Notropis heterolepis), blackchin shiner (Notropis heterodon), tadpole madtom (Noturus gyrinus), banded killifish (Fundulus diaphanus), pumpkinseed (Lepomis gibbosus), Iowa darter (Etheostoma exile), and brook stickleback (Culea inconstans). Several other species are largely restricted to vegetated waters but are either uncommon or rare in Lake St. Clair. These are the spotted gar (Lepisosteus oculatus), muskellunge (Esox masquinongy), pugnose shiner (Notropis anogenus), and pugnose minnow (Notropis emiliae). However, a significant native, self-sustaining population of muskellunge exists in Lake St. Clair (Haas 1978) and spawns in the delta wetlands. Here, it is harvested by the Chippewa Indians on the Walpole Island Indian Reserve, Ontario.

Several fish species found in the Lake St. Clair basin are common to abundant in wetlands and adjacent waters, although they are often associated with non-vegetated habitats as well. The gizzard shad (Dorosoma cepedianum), goldfish (Carassius auratus), carp (Cyprinus carpio), fathead minnow (Pimephales promelas), black bullhead (Ictalurus melas), brown bullhead (Ictalurus nebulosus), yellow bullhead (Ictalurus natalis), bluegill (Lepomis macrochirus), largemouth bass (Micropterus salmoides), white crappie (Pomoxis annularis), and black crappie (Pomoxis nigromaculatus) generally occur in quiet, low-gradient waters with bottoms of mud or clay. These species are generally cover-oriented and may be common in sheltered riverine and lacustrine coastal wetlands along Lake St. Clair. All except the gizzard shad, goldfish, bluntnose minnow, and fathead minnow are significant game species.

The mimic shiner (Notropis volucellus), sand shiner (Notropis stramineus), lake chubsucker (Erimyzon sucetta), spotted sucker (Minytrema melanops), rock bass (Ambloplites rupestris), green sunfish (Lepomis cyanellus), smallmouth bass (Micropterus dolomieui), johnny darter (Etheostoma nigrum), logperch (Percina caprodes), and mottled sculpin (Cottus bairdi) are generally associated with lotic waters and clean sand or gravel bottoms, but they are also common in coastal lake waters, where they may utilize deep lacustrine coastal wetlands with sand or gravel bottoms. The green sunfish, rock bass, and smallmouth bass, are significant game species. Among commercial and game species the walleye (Stizostedion v. vitreum) and native or introduced salmonids apparently have little direct association with coastal wetlands. Other species of recreational or commercial importance, including yellow perch (Perca flavescens), white bass (Morone chrysops), and freshwater drum (Aplodinotus grunniens), as well as important forage species, including spot-tail shiner (Notropis hudsonius) and emerald shiner (Notropis atherinoides), are ubiquitous in the coastal zone of Lake St. Clair and may be locally commmon in certain coastal wetlands.

Known fish spawning areas in the St. Clair system have been documented by the U.S. Fish and Wildlife Service (Goodyear et al. 1982a,b,c), including site specific information on fish spawning and nursery areas for sturgeon (Acipenser fulvescens), alewife (Alosa pseudoharengus), rainbow trout (Salmo gairdneri), smelt (Osmerus mordax), white sucker (Catostomus commersoni), smallmouth bass, rock bass, walleye, and yellow perch. Goodyear and her colleagues summarized information on all past and presently known spawning areas in Lake St. Clair and the St. Clair River. These areas include the marshy and shallow bay areas along the shoreline and the wetlands of the delta. While the relationship of submersed aquatic macrophytes in littoral waters to fishery productivity is not fully understood, preliminary results of recent studies indicate that the submersed littoral macarophyte habitat is important to fish production in these waters (Schloesser and Manny 1982).

Walleye migrate through Lake St. Clair and use the channels of the St.

Clair Delta for spawning areas (Figure 34). Tagging studies (Ferguson and Derksen 1971; Wolfert et al. 1975) indicated considerable movement of walleye between Lake St. Clair and adjoining lakes Erie and Huron. Each lake has many known and some suspected spawning areas. Since walleyes prefer to spawn close to their place of origin (Eschmeyer 1950; Ferguson and Derksen 1971) there appears to be a number of semi-discrete stocks coexisting in these lakes. Tagging studies have not been sufficiently intense, however, to delimit these stocks within time and space.

Yellow perch (Perca flavescens) is one of the most abundant fish in Lake St. Clair and is known to spawn over aquatic vegetation in most inshore areas of the lake (Figure 35), but it is not known whether discrete stocks exist. Commercial fishermen believe that Lake Huron fish can be identified by shape and color in Lake St. Clair. Similarly, Ohio fishermen postulate that a postspawning movement of large yellow perch comes into the western basin of Lake Erie, presumably from Lake St. Clair. There is no evidence to support or reject these views. The scant tagging that has been carried out with yellow perch suggests that they are capable of moving between the lake systems (Johnston 1977). However, the maintenance of a number of age-groups in Lake St. Clair is in direct contrast to the situation in Lake Erie.

Sturgeon, a threatened species in Michigan and an endangered species in Ohio, are common in the deeper portions of the delta and channels. The major known spawning area for Lake St. Clair sturgeon is the North Channel of the St. Clair River (Figure 36). These sturgeon migrate up to the North, South, and Middle channels to spawn at a site in the North Channel; young-of-the-year sturgeon migrate from this spawning site to the marsh between Bouvier and Goose Bays, where they are found among the rushes (Goodyear et al. 1982a,b). The channels are also productive fishing areas for muskellunge, smallmouth bass, largemouth bass, freshwater drum, and northern pike. Figures 37 and 38 depict spawning and nursery areas for several of these species.

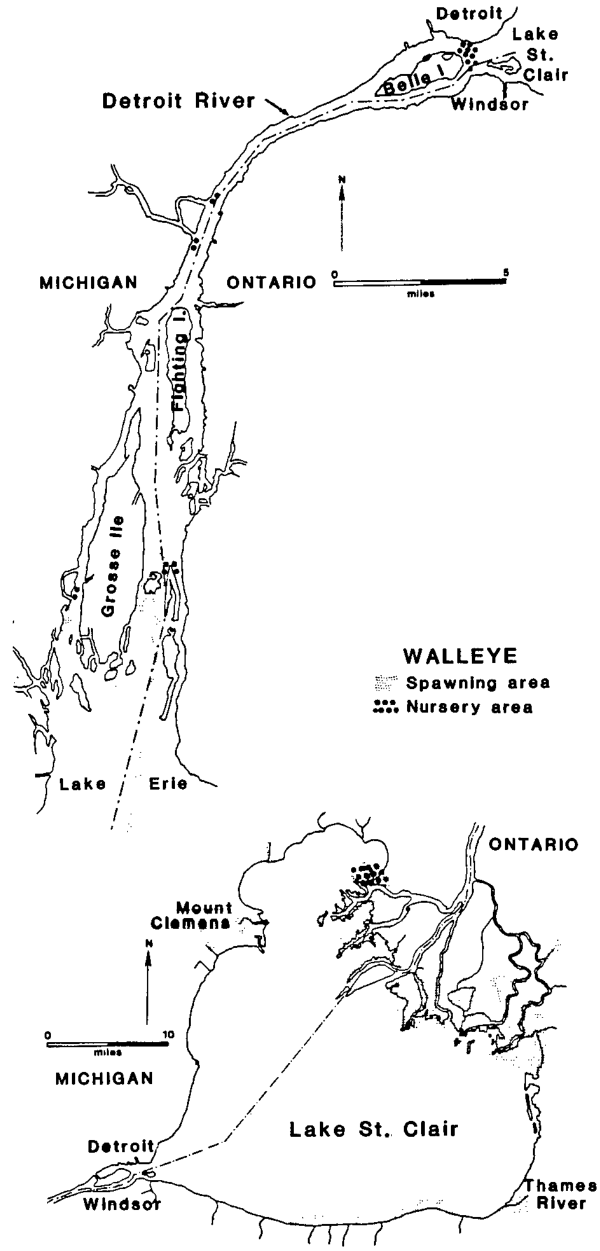

Figure 34. Walleye spawning and nursery areas in the Detroit River and Lake St. Clair (Goodyear et al. 1982b,c).

Lake St. Clair has been acclaimed one of the best fishing areas in North America (Figure 39). This fishery is fostered by the marsh habitats which sustain species number and diversity. Sport fishing in wetlands exhibits high economic values. Jaworski and Raphael (1978) calculated the value of Michigan's coastal wetlands with

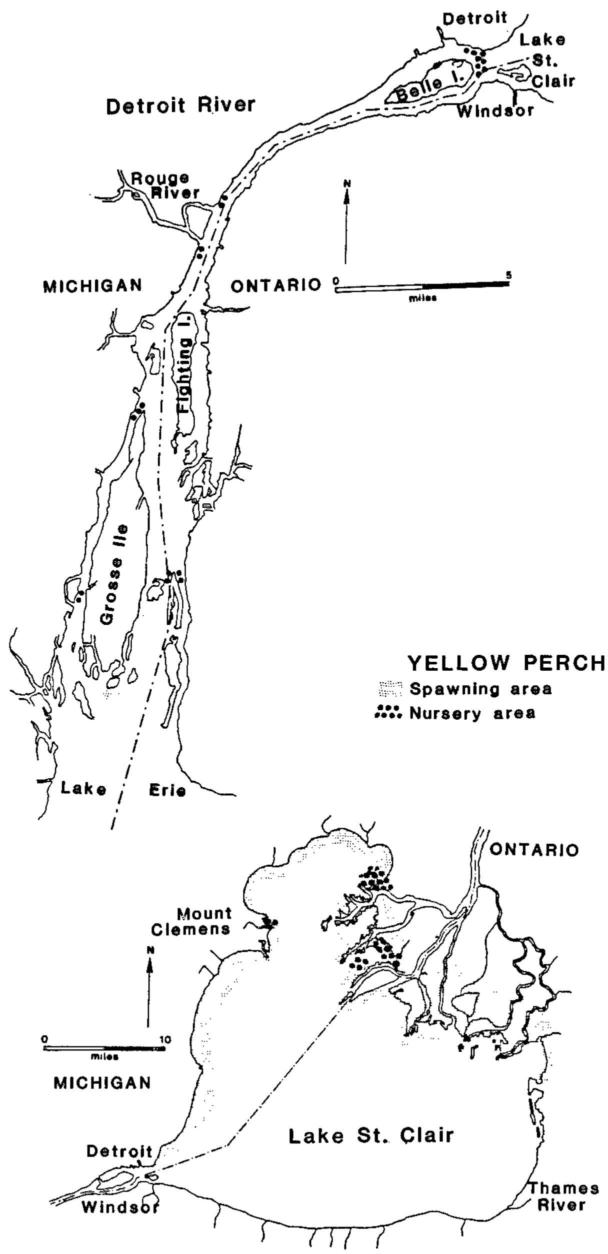

Figure 35. Yellow perch spawning and nursery areas in the Detroit River and Lake St. Clair (Goodyear et al. 1982b,c).

respect to sport fishing at $116/wetland hectare/year. Lake St. Clair exhibits the highest sport fishery value for Great Lakes coastal wetlands because of its proximity to Detroit and the high quality of angling for walleye, smallmouth bass, and yellow perch (Table 20). Current estimates indicate that the St. Clair Delta wetlands average 8 to 16 angler-days/wetland hectare/year (Herdendorf et al. 1981c).

Major game fish species which furnish a recreational fishery in Bouvier Bay Wetland, known also as St. John's Marsh, include northern pike, largemouth bass, yellow perch, bullheads, and various panfish (Pospichal 1977). Recreational fishing is popular from shore sites as well as from boats in the shallow bays and channels of St. John's Marsh. Within the St. Clair Flats State Wildlife Area on Dickinson Island and on Harsens Island, recreational fishing is popular for muskellunge, northern pike, walleye, yellow perch, smallmouth bass, channel catfish (Ictalurus punctatus), bullheads, bluegill, other sunfishes, crappie, rock bass, white bass, lake sturgeon, coho salmon (Oncorhynchus kisutch), steelhead trout and other species. The area is also a prolific producer of bait-minnows. Bow and arrow fishing for carp is a growing springtime activity, which generates 3,000 to 5,000 angler-days of recreation per year (Pospichal 1977). Ice fishing (commonly by hook and line) is also an active sport in January and February. Common species pursued include yellow perch (85%), sunfish (10%), walleye, and northern pike. More than 95% of recreation ice fishing is for wetland associated species.

Other than species composition and recreational use of the fish fauna of Lake St. Clair, knowledge of the wetland fishery of Lake St. Clair is lacking in several respects. Other important considerations include: 1) actual relationships of the species to the wetlands in terms of their utilization for spawning, nursery, and feeding areas, 2) fish community structure, 3) niche occupation, and 4) interspecific relationships within wetlands. The coastal wetlands of Lake St. Clair appear to support a mixed fish fauna of warmwater and coolwater species. In addition to wetland dependent species, many species common in other coastal habitats are also common in coastal wetlands, depending on condition of shelter, bottom type, water clarity, water depth, and density of vegetation. Because of the obvious voids in fisheries information within coastal wetlands, research in this area ranks high priority.

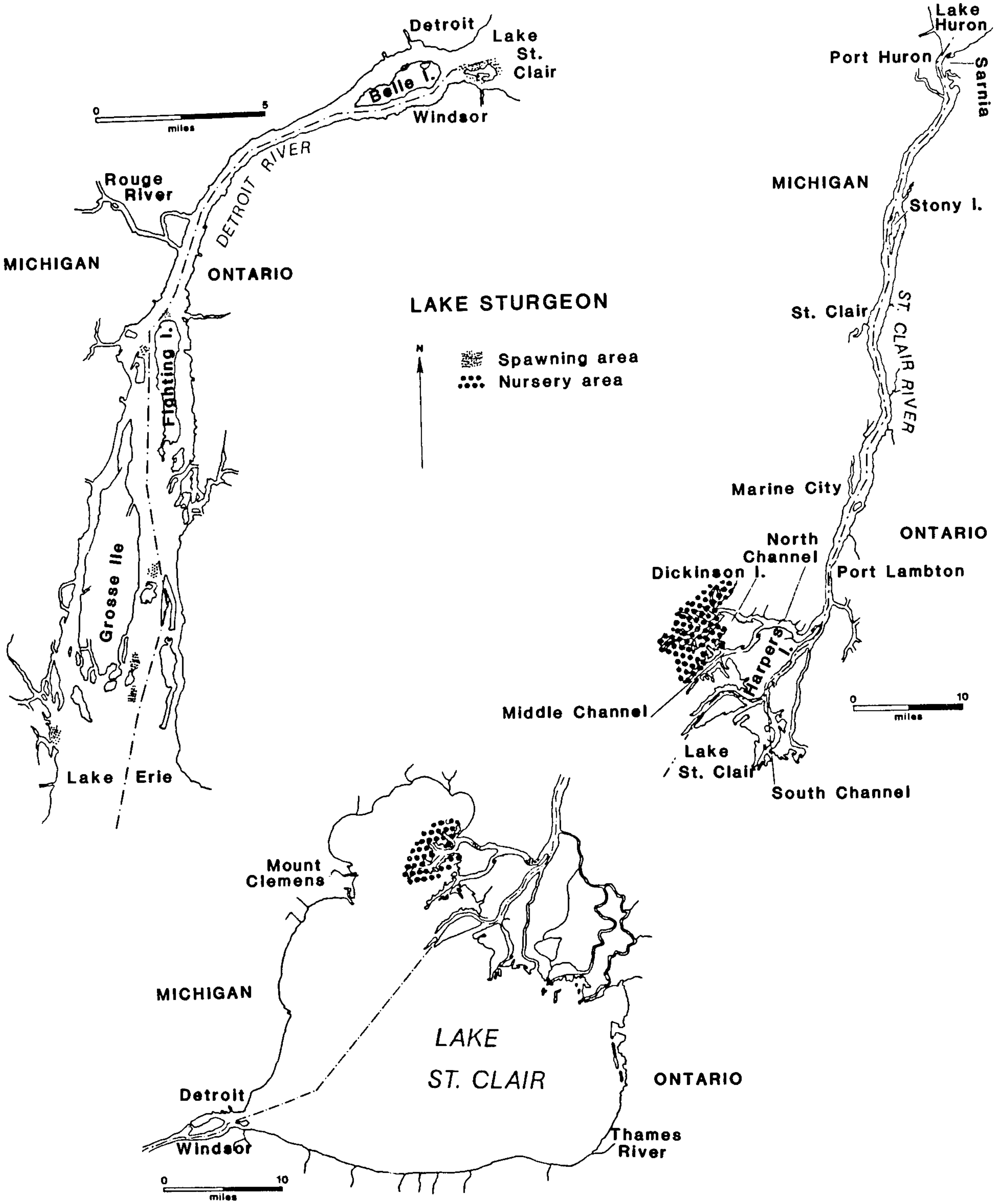

Figure 36. Lake sturgeon spawning and nursery areas in the Detroit River, Lake St. Clair, and St. Clair River (Goodyear et al. 1982a,b,c).

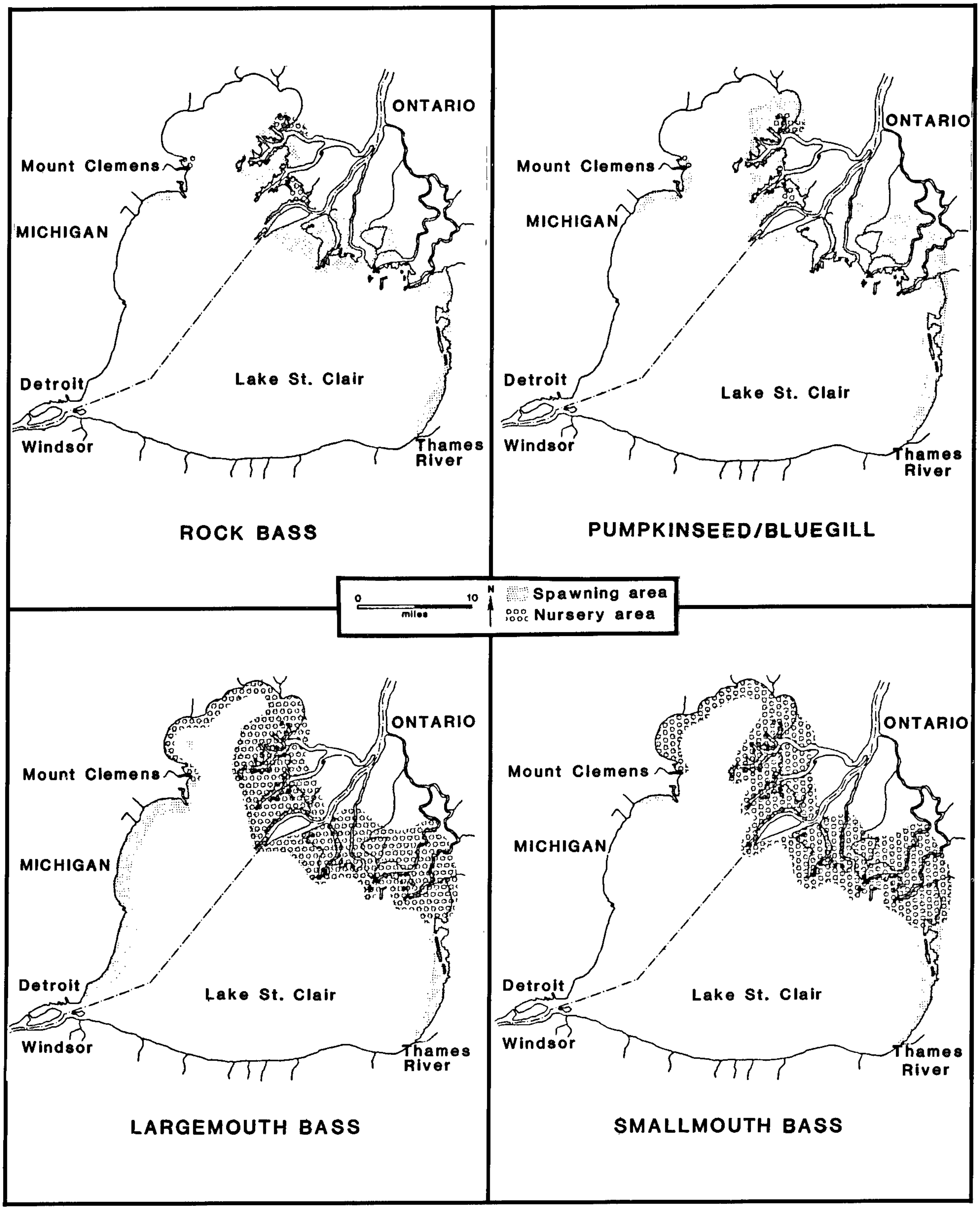

Figure 37. Rock bass, pumpkinseed/bluegill, largemouth bass, and smallmouth bass spawning and nursery areas in Lake St. Clair (Goodyear et al. 1982b).

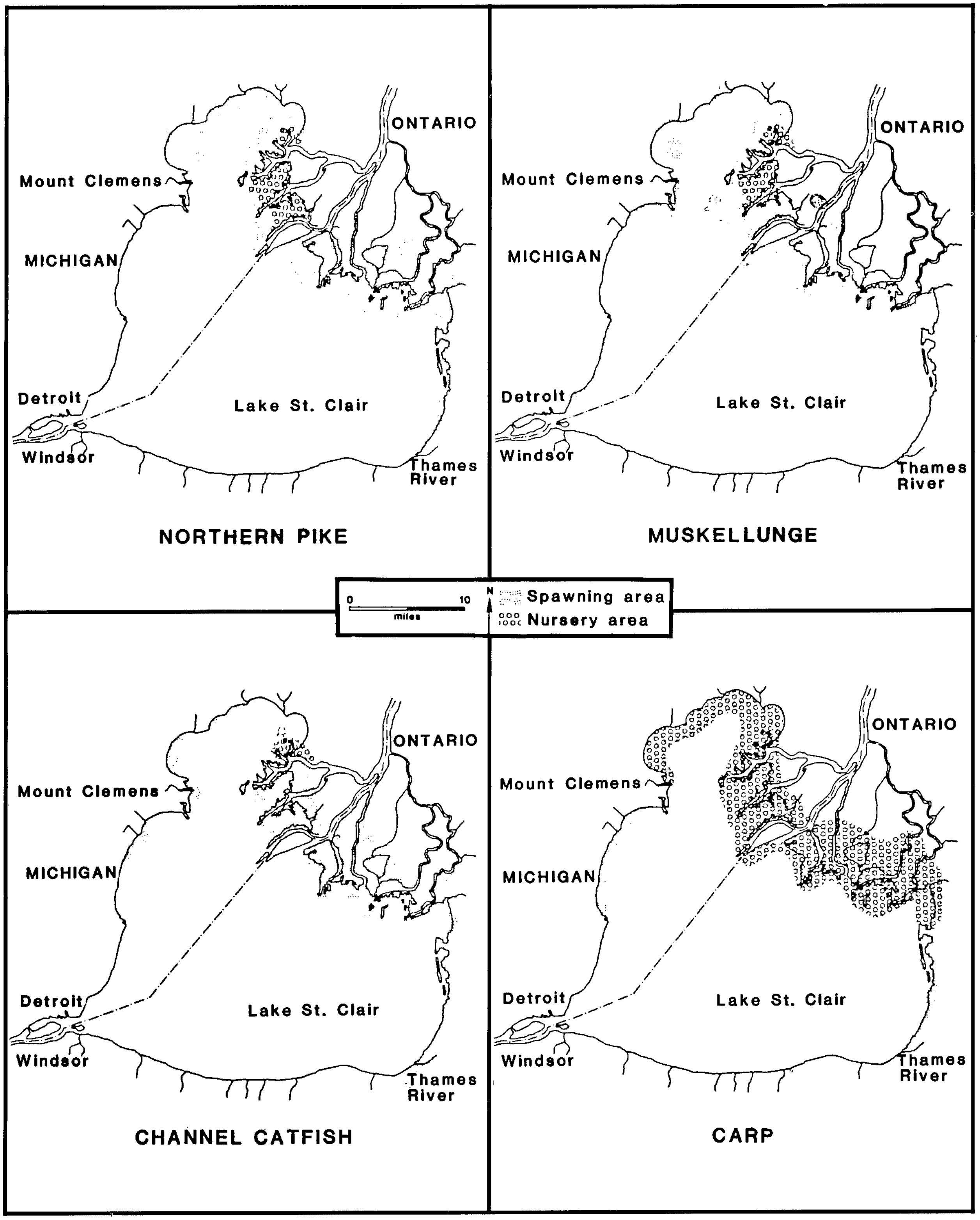

Figure 38. Northern pike, muskellunge, channel catfish, and carp spawning and nursery areas in Lake St. Clair (Goodyear et al. 1982b).

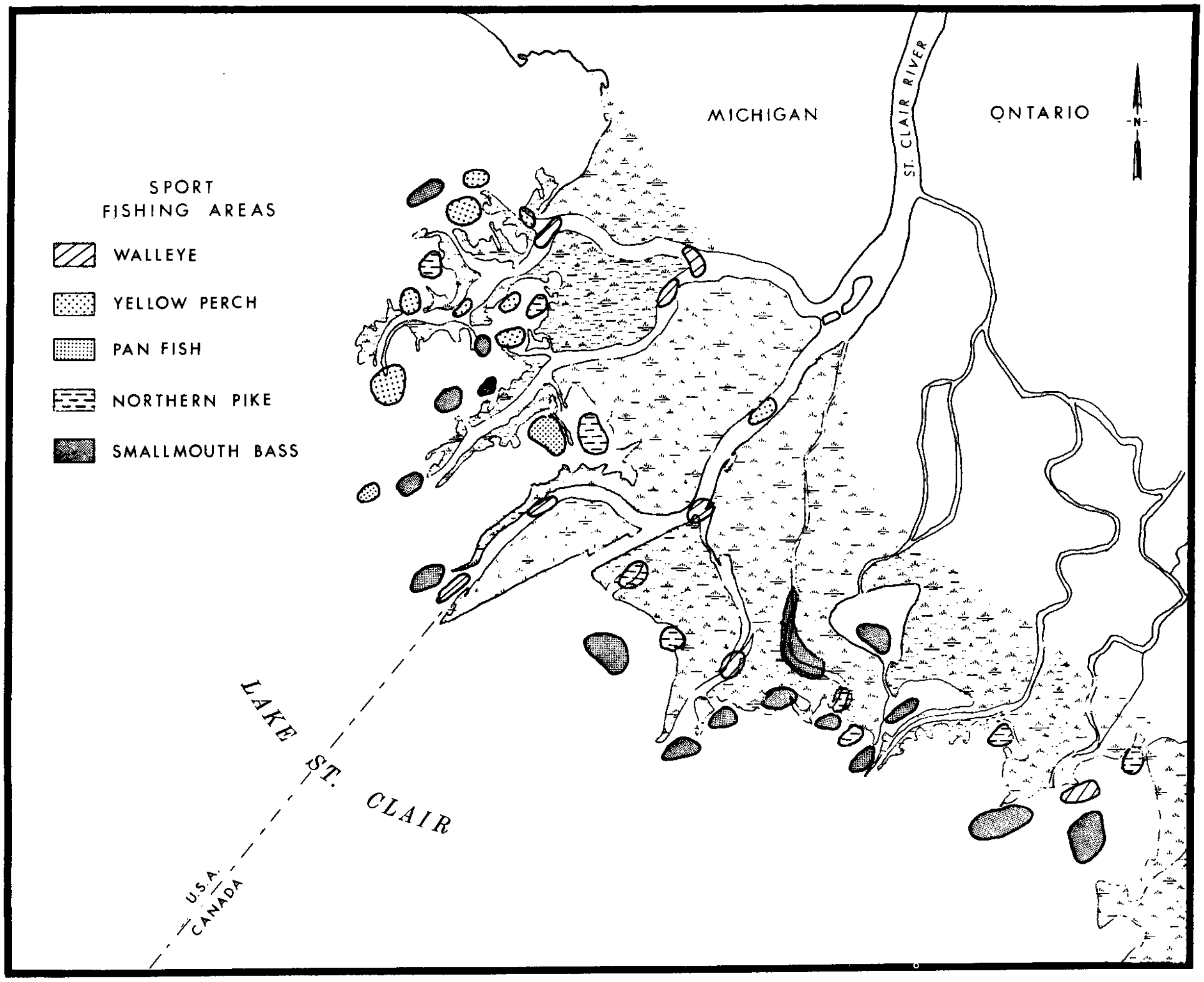

Figure 39. Sport fishing areas by species in the vicinity of St. Clair Delta wetlands (Lake St. Clair Advisory Committee 1975).

3.5 AMPHIBIANS AND REPTILES

The assemblage of amphibians and reptiles reported for the Lake St. Clair region can be divided into four major groups: 1) those species almost always found in wetlands and somehow dependent on wetland habitats to the degree that they are uncommon elsewhere, 2) aquatic and semiaquatic species found in a wide range of lowland wet habitats, including coastal wetlands, 3) terrestrial species which enter water or wetlands only incidentally or to breed, and 4) aquatic and semiaquatic species found primarily in upland or lotic waters and not common to coastal wetlands (Herdendorf et al. 1981c). The latter are not disussed in this report. Four species recorded in the literature as occurring in the coastal zone of Lake St. Clair are largely wetland dependent: mudpuppy (Necturus maculosus), red-spotted newt (Notophthalmus viridescens), eastern fox snake (Elaphe vulpina gloydi), and eastern massasauga (Sistrurus c. catenatus). The mudpuppy is largely an open lake species which is most common around large lacustrine wetlands with submersed vegetation, whereas the red-spotted newt is found primarily in small ponds and sheltered palustrine or riverine wetlands. The eastern fox snake is common in large coastal emergent-type

Table 20. Average annual number of sport fish taken from Michigan waters of Lake St. Clair and connecting waterways (1975-1979).[a]

Species	Lake St. Clair	St. Clair River	Detroit River	Total individuals
Lake trout	722	1,217	273	2,212
Rainbow/steelhead	1,997	4,434	744	7,175
Brown trout	1,133	1,637	278	3,048
Coho salmon	1,082	4,591	2,813	8,486
Chinook salmon	830	1,684	380	2,894
Walleye/sauger	453,338	273,843	316,655	1,043,836
Bass	224,933	32,764	51,494	309,191
Northern pike/musky	79,362	12,826	14,926	107,114
Yellow perch	3,471,516	256,617	785,934	4,514,067
Sunfish/bluegill	829,607	107,747	263,083	1,200,437
Crappie/white bass	214,107	39,265	203,866	457,238
Bullhead/catfish	144,858	21,111	95,209	261,178
Rock bass	68	272	408	748
Sucker	77,124	19,176	36,658	132,958
Whitefish/cisco	5,944	608	676	7,228
Other	144,618	57,724	67,022	269,364
Angler days	1,079,031	320,701	452,376	1,852,108
Fishermen	100,622	32,523	41,674	174,819

[a]Data source: Michigan Department of Natural Resources (unpublished data).

wetlands, but the rarer eastern massasauga is primarily restricted to swamp forest and bogs.

Amphibians found in a wide range of lowland wet or aquatic habitats in the Lake St. Clair coastal zone include the blue-spotted salamander (Ambystoma laterale), spotted salamander (Ambystoma maculatum), four-toed salamander (Hemidactylium scutatum), eastern tiger salamander (Ambystoma tigrinum), gray treefrog (Hyla versicolor), northern spring peeper (Hyla crucifer), western chorus frog (Pseudacris triseriata), Blanchard's cricket frog (Acris crepitans blanchardi), bullfrog (Rana catesbeiana), green frog (Rana clamitans melanota), pickerel frog (Rana palustris), and northern leopard frog (Rana pipiens). The salamanders may often occur in moist terrestrial habitats, but their larvae are always aquatic. Aquatic and semi-aquatic reptiles which probably occur in Lake St. Clair coastal wetlands or their border lands include the northern ringneck snake (Diadophis punctatus edwardsi), eastern milk snake (Lampropeltis t. triangulum), northern water snake (Natrix s. sipedon), northern brown snake (Storeria d. dekayi), northern red-bellied snake (Storeria o. occipitomaculata), Butler's garter snake (Thamnophis butleri), northern ribbon snake (Thamnophis sauritus septentrionalis), eastern garter snake (Thamnophis s. sirtalis), snapping turtle (Chelydra s. serpentina), Blanding's turtle (Emydoidea blandingi), eastern spiny softshell, (Trionyx s. spiniferus), and midland painted turtle (Chrysemys picta marginata).

Several amphibians of the Lake St. Clair coastal zone are largely terrestrial, although they are found in lowland areas and are dependent on water for breeding. Consequently the adults or larvae may occur in coastal wetlands or

their margins at least seasonally. These species include the red-backed salamander (*Plethodon cinereus*), the American toad (*Bufo americanus*), and the wood frog (*Rana sylvatica*). Terrestrial reptiles which may occur in the margins of Lake St. Clair coastal wetlands or incidentally in the wetlands themselves include the eastern smooth green snake (*Opheodrys v. vernalis*), blue racer (*Coluber constrictor foxi*), and black rat snake (*Elaphe o. obsoleta*).

Although few species of reptiles and amphibians are absolutely dependent on the coastal wetlands of Lake St. Clair for habitat, the continued abundance of most species in the coastal zone is probably dependent on the presence of extensive coastal wetlands. The relatively undisturbed coastal habitat along most of the St. Clair Delta probably supports a present herpetofauna similar to that of pre-settlement times, both in composition and relative abundance of species. Appendix J lists the species known or presumed to occur in or adjacent to the coastal wetlands; because of the scarcity of published records, this list is somewhat speculative.

The presence of water, food, and cover, and the relative isolation from the cultural development which occurs around most other bodies of water are among the factors that contribute to the importance of wetlands in maintaining the coastal zone herpetofauna. The recreational or commercial importance of the coastal herpetofauna is unknown, but the bullfrog, green frog, eastern spiny softshell, and snapping turtle are edible species which may be harvested. In addition, reptiles and amphibians such as the northern water snake and the snapping turtle, serve as food sources for many species of fish, birds, and mammals, or may themselves be predators of economically important fish and wildlife. Beyond general background on the occurrence and relative abundance of reptiles and amphibians in the coastal wetlands, little published information exists pertaining to population, community structure, and dynamics of the herpetofauna.

The eastern fox snake is listed as threatened by the State of Michigan. This species is wetland-dependent and was once common and restricted to coastal emergent wetlands and wetland margins of western Lake Erie and the coast of Lake St. Clair. The black rat snake is also listed as threatened in Michigan and may occur in drier margins of Lake St. Clair coastal wetlands. The eastern massasauga is a candidate for Federal listing on the threatened/endangered species list. The following species, considered rare in Michigan, may also occur in these coastal wetlands: eastern spiny softshell, spotted turtle (*Clemmys guttata*), and four-toed salamander.

3.6. BIRDS

The extensive wetlands of the St. Clair Delta are utilized for nesting and during migration by waterfowl, wading birds, gulls, terns, and shorebirds. Appendix K lists the important bird species which occur in the vicinity of the Lake St. Clair wetlands. Waterfowl commonly observed in the wetlands include mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*), blue-winged teal (*Anas discors*), wood duck (*Aix sponsa*), American wigeon (*Anas americana*), and northern shoveler (*Anas clypeata*). In addition, canvasback (*Aythya valisineria*), scaup (*Aythya* spp.), ruddy duck (*Oxyura jamaicensis*), and hooded merganser (*Lophodytes cucullatus*) utilize the habitat for nesting. Several endangered and threatened species (Michigan) of birds have been reported in the coastal zone. Osprey (*Pandion haliaetus*) and the Caspian tern (*Sterna caspia*) have been reported in scattered localities along the shoreline. Nesting colonies of yellow-headed blackbird (*Xanthocephalus xanthocephalus*), black tern (*Chlidonias niger*), and common tern (*Sterna hirundo*) have been observed in several wetlands. The common tern is presently on the Michigan endangered species list.

Waterfowl are a most important component of the biotic environment. The importance of the Lake St. Clair wetlands to ducks, geese, and other waterfowl is based primarily on the location of these wetlands in relation to waterfowl flyways, the productivity (in terms of waterfowl

foods) of the wetlands, and the decline of other coastal wetland systems. Except for that of mallard, black duck and blue-winged teal, nesting appears to be a secondary use of these wetlands with feeding and resting during migration being of primary importance.

Waterfowl

Based on waterfowl feeding and resting use during migration as well as on duck harvest and production of young, the wetlands and associated open waters of Lake St. Clair may be the most important wetland system in the Great Lakes region with the possible exception of Long Point in Lake Erie. With reference to the Great Lakes-Chesapeake Bay migration corrider, the principal flight paths of the tundra swan, formerly whistling swan, (Cygnus columbianus), canvasback, bufflehead (Bucephala albeola), and ruddy duck include a resting stopover in Lake St. Clair (Bellrose 1976). In reference to waterfowl harvesting in Michigan, St. Clair County, which includes most of the wetland on the American side of Lake St. Clair, is the leading harvest county (Carney et al. 1975). Production data for the Bouvier Bay (including St. John's Marsh) and Harsens Island wetlands reveal an average of 240 young produced per km^2 (Herdendorf et al. 1981c).

Important literature sources regarding the waterfowl use of the wetlands are Jaworski and Raphael (1978) as well as Herdendorf et al. (1981c). The latter source is especially important in regard to the Bouvier Bay, Dickinson Island, and Harsens Island wetlands. The St. Clair Flats State Game Area comprises the lower portions of Harsens Island and Dickinson Island, plus the two former areas of the Lake St. Clair National Wildlife Refuge, one at the mouth of North Channel in Anchor Bay, and another in between the end of Middle Channel and Channel A Bout Rond.

In Ontario, the Canadian Wildlife Service (Dennis and Chandler 1974, Dennis et al. 1981) have documented the utility of wetlands with regard to waterfowl. In terms of total use during migration, the Lake St. Clair wetlands rank second to Long Point (Lake Erie), Ontario. The coastal marshes are presently the most important staging areas in southern Ontario for mallard, black duck, Canada goose (Branta canadensis), and tundra swan. Significant portions of the North American population of canvasback, redhead (Aythya americana), and tundra swan also utilize the Lake St. Clair marshes during migration staging periods.

Walpole Island possesses extensive marshes, particularly at its southern end where the shore fronts on Lake St. Clair. There are five major islands that make up the 24,000-hectare Walpole Island Indian Reserve. Here many nesting species of birds rare in both the region and Ontario as a whole have been observed, including canvasback, redhead, ruddy duck, northern harrier (Circus cyaneus), little gull (Larus minutus), Forster's tern (Sterna forsteri), and king rail (Rallus elegans) (Goodwin 1982). Wooded areas of the island include sections of oak savannah which accommodate a rookery of black-crowned night-herons (Nyticorax nyticorax) and great egrets (Casmerodius albus).

As indicated in Table 21, a diversity of waterfowl rely on the St. Clair Delta wetlands. Waterfowl use during migration is more important than use of these wetlands for breeding purposes. Moreover, ducks are much more numerous than are swans and geese. With regard to dabbling ducks, the most abundant migrants include: mallard, black duck, American wigeon as well as pintail (Anas acuta), blue-winged teal, and green-winged teal (Anas crecca). Among the more abundant migrant diving ducks are canvasback, greater scaup (Aythya marila), lesser scaup (Aythya affinis), and redhead as well as common goldeneye (Bucephala clangula) and bufflehead.

The use of the St. Clair Delta wetlands for feeding by both dabbling and diving ducks is of prime importance (Table 22). Plant foods from shallow marshes and waste grains from nearby agricultural fields are especially important in the diet of dabbling ducks, particularly mallards and black ducks as well as Canada geese, whereas submersed aquatic plants and their associated invertebrate fauna constitute important food items for diving ducks such as canvasback, redhead, and scaup (Jaworski and Raphael 1978). Corn

Table 21. Birds observed in St. Clair Delta wetlands (1975-1977).[a]

Species	Bouvier Bay[b]	Dickinson Island	Harsens Island
Tundra swan	x		x
Canada goose	x		x
Snow goose	x		
Mallard	x	x	x
Black duck	x	x	
Gadwall	x	x	
Pintail	x	x	
American wigeon	x	x	
Green-winged teal	x	x	
Blue-winged teal	x	x	x
Northern shoveler	x	x	x
Wood duck	x	x	x
Redhead	x	x	x
Ring-necked duck	x	x	x
Canvasback	x		x
Greater and lesser scaups	x	x	x
Common goldeneye			x
Bufflehead	x		x
Ruddy duck	x		
Hooded and common mergansers	x	x	x
Horned grebe			x
Pied-billed grebe	x		
Belted kingfisher	x		
Sedge and marsh wrens	x		
Great blue heron	x	x	x
Green-backed heron	x		
Great and cattle egrets	x		
Black-crowned night-heron	x		
American and least bitterns	x		
King and Virginia rails	x		
Sora	x		x
Common moorhen	x		
American coot	x	x	
Herring gull	x	x	x
Ring-billed gull	x		
Forster's and black terns	x		
Common tern	x	x	x
Eastern meadowlark		x	
Yellow-headed blackbird	x		
Red-winged blackbird	x	x	x
Common snipe	x		
American woodcock		x	
Cooper's hawk	x		
Red-tailed hawk	x	x	
Rough-legged hawk	x	x	
Northern harrier	x		

[a]Data source: Herdendorf et al. (1981c).

[b]Note: Bouvier Bay survey included St. John's Marsh; other surveys less intense.

Table 22. Productivity and seasonal abundance of waterfowl in Bouvier Bay marshes and Harsens Island interior wetlands (1974).[a]

Area and waterfowl	Summer production		Fall migration		Spring migration	
	Adult pairs (no/km2)	Young	Total pop.	Duration (wks)	Total pop.	Duration (wks)
Bouvier Bay						
Dabbling ducks	35	222	4,800	4-10	4,900	3-4
Divers	2	14	200	-	5,000	3-4
Geese	1	4	0	0	0	0
Swans	0	0	0	0	0	0
Total	38	240	5,000		9,900	
Harsens Island						
Dabbling ducks	33	210	1,400	4-10	1,500	4-5
Divers	4	22	100	10	2,400	4-5
Geese	1	5	-	-	-	-
Swans	38	237	1,500	-	3,900	-
Total	76	474	3,000		7,800	

[a]Data sources: Herdendorf et al. (1981c), Michigan Department of Natural Resources (unpublished data).

and other grains grown on the Harsens Island State Game Area and on the upland portions of the Canadian side of the delta attract dabbling ducks and Canada geese. In contrast, submersed aquatic plants in the diet of diving ducks include wild celery, pondweeds, and waterweed.

The significance of the plant and invertebrate food base of the St. Clair Delta wetlands in relation to waterfowl can not be overstated. An important study by Dawson (1975) of Anchor Bay in northern Lake St. Clair, indicates that only a small percentage of the preferred aquatic plants and invertebrates available to migrating waterfowl in Lake St. Clair wetlands are currently being utilized. Waterfowl food supplies are especially important during spring migration because preferred foods are generally less abundant and breeding females must arrive in good condition on the breeding grounds. Thus the spring migration is less restricted to specific feeding areas and waterfowl can be observed in lakes and wetlands which they did not frequent in the fall. For example, note in Table 22 that diving ducks are more numerous in the relatively shallow Bouvier Bay and Harsens Island wetlands in spring than in the fall migration season. Waterfowl migration is discussed in more detail in Section 4.3.

With regard to production of waterfowl in the wetlands along Lake St. Clair, these wetlands appear to be of moderate importance only. Some preliminary data collected by Jaworski and Raphael (1978) suggested that Michigan's coastal wetlands have a duck nesting density of 32 breeding pairs per km^2 and that goose and swan nesting was insignificant. Data reveal that the pairs

of dabbling ducks slightly exceed this preliminary average, but that pairs of diving ducks were much less than the mean (Table 22) . Herdendorf et al. (1981c) reported that mallard, blue-winged teal, and cinnamon teal are the most common nesters in the delta wetlands along with smaller numbers of black duck, wood duck, pintail, redhead, and ruddy duck. Small but significant numbers of the relatively rare redhead duck nest in St. John's Marsh, on lower Harsens Island, and along coastal Walpole Island. Both mallard and blue-winged teal are classified as meadow nesters, but the mallard exhibits great versatility in regard to selection of potential nesting sites.

Lake St. Clair has long been renowned as an excellent duck hunting area. Hunting pressure from both the land and water is common on the American and Canadian sides of the delta. The main species harvested in these coastal wetlands are the mallard, along with lesser numbers of black duck, pintail, and teal (Table 23) . However, in open-water areas of Lake St. Clair, where hunting from boats and floating blinds prevails, the majority of the ducks harvested are divers, i.e., scaup and the now restricted canvasback and redhead, rather than dabbling ducks.

Table 23. Species composition of ducks harvested in the St. Clair Flats State Game Area (1974-1975).[a]

Species	Annual harvest (avg. no. individ.)	Percent of total
Mallard, including domestic	4,362	76.30
Black duck and hybrids	498	8.71
Pintail	242	4.23
Green-winged teal	173	3.03
American wigeon	138	2.41
Ring-necked duck	78	1.36
Blue-winged teal	71	1.24
Scaup	34	0.60
Gadwall	30	0.53
Wood duck	28	0.49
Merganser	19	0.33
Bufflehead	18	0.31
Northern shoveler	10	0.18
Common goldeneye	9	0.16
Redhead	4	0.07
Ruddy duck	3	0.05
Oldsquaw	0	0.00
Canvasback	0	0.00
Scoter	0	0.00
TOTAL	5,717	100.00

[a]Data source: Jaworski and Raphael (1978).

Shorebirds, Wading Birds, and Raptors

The type of shores range from sandy beaches to mudflats. The beaches attract small flocks of shorebirds in migration. Those species commonly seen feeding are killdeer (*Charadrius vociferus*), spotted sandpiper (*Actitis macularia*), sanderling (*Calidris alba*) and semipalmated sandpiper (*Charadrius semipalmatus*). Whereas waterbirds, such as herons and egrets, gather to feed in the mud flats near larger streams.

Nesting species in the St. Clair Flats (Figure 40) include such species as the common snipe (*Gallinago gallinago*), pied-billed grebe (*Podilymbus podiceps*), American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*), king rail, sora (*Porzana carolina*), American coot (*Fulica americana*), black and common terns, marsh wren (*Cistothorus palustris*), and swamp sparrow (*Melospiza georgiana*). Lake St. Clair wetlands support the following nesting waterbirds in wooded habitats: great blue heron (*Ardea herodias*), black-crowned night-heron, green-backed heron (*Butorides striatus*), great egret, American woodcock (*Scolopax minor*), belted kingfisher (*Ceryle alcyon*), bald eagle (*Haliaeetus leucocephalus*), and osprey.

Investigations in 1954 of a rookery on Dickinson Island found approximately 350 pairs of great blue herons and 20 pairs of black-crowned night-herons along with seven pairs of great egrets. Their numbers have declined over the past three decades. Nearby Harsens Island supports a rookery of black-crowned night-herons (U.S. Army Corps of Engineers 1974).

Herons are a solitary bird except when breeding. They are colonial nesters

Figure 40. Least bittern (Ixobrychus exilis) with young in broad-leaved cattail (Typha latifolia) nest (Michigan Department of Natural Resources).

who require a habitat with an abundance of twigs and sticks for nest-building. These long-legged waders prefer a diet of fish, but will also feed on insects, crustaceans, amphibians, reptiles, mollusca, and rodents (Figure 41). They are strong fliers and are known to fly great distances in search of food. For example in Lake Erie, herons fly 15 km from their rookery on West Sister Island to feed in the marshes at Locust Point on the Ohio mainland (Meeks and Hoffman 1980).

Wading birds usually forage in the shorelines of the tributary streams and within the coastal marshes of the St. Clair Delta. Their diet consists of fish for the most part, but crayfish and insects are also consumed in significant quantities.

Short-eared owls (Asio flammeus), northern harriers (Circus cyaneus), rough-legged hawks (Buteo lagopus), red-tailed hawks (Buteo jamaicensis), and Cooper's hawks (Accipiter cooperii) have been reported in St. John's Marsh in Bouvier Bay (Pospichal 1977). Bald eagle and osprey nest in wooded habitats associated with delta wetlands (Kelley et al. 1963).

3.7 MAMMALS

The wetlands of Lake St. Clair are important habitat for several species of mammals (Appendix L). Wetlands are essential for muskrat (Ondatra zibethicus) and mink (Mustela vison). The Virginia opossum (Didelphis virginiana), striped skunk (Mephitis mephitis), and red fox (Vulpes fulva) are commonly observed in the wetlands. Furbearers are a valuable resource in many coastal wetlands, particularly those associated with the Lake St. Clair Delta, including St. John's Marsh (a portion of Bouvier Bay wetlands), Dickinson Island, Harsens Island, Walpole Island, and Mitchell Bay wetlands. Fifteen species of mammals have been reported from the delta islands (Hayes 1964, U.S. Army Corps of Engineers 1974): Virginia opossum, eastern cottontail (Sylvilagus floridanus), European hare (Lepus capensis), woodchuck (Marmota monax), fox squirrel (Sciurus niger), gray squirrel (Sciurus carolinensis), red squirrel (Tamiasciurus hudsonicus), muskrat, red fox, raccoon (Procyon lotor), weasel (Mustela frenata), mink, badger (Taxidea taxus), striped skunk, and white-tailed deer (Odocoileus virginianus). Limited deer and upland game hunting is permitted on the delta islands.

Muskrats

The principal mammal inhabiting Lake St. Clair wetlands in terms of occurrence and economic value is the muskrat. Based on its feeding and lodging habits, the density of muskrats per unit of coastal wetland can be estimated. Jaworski and Raphael (1978) determined that Macomb

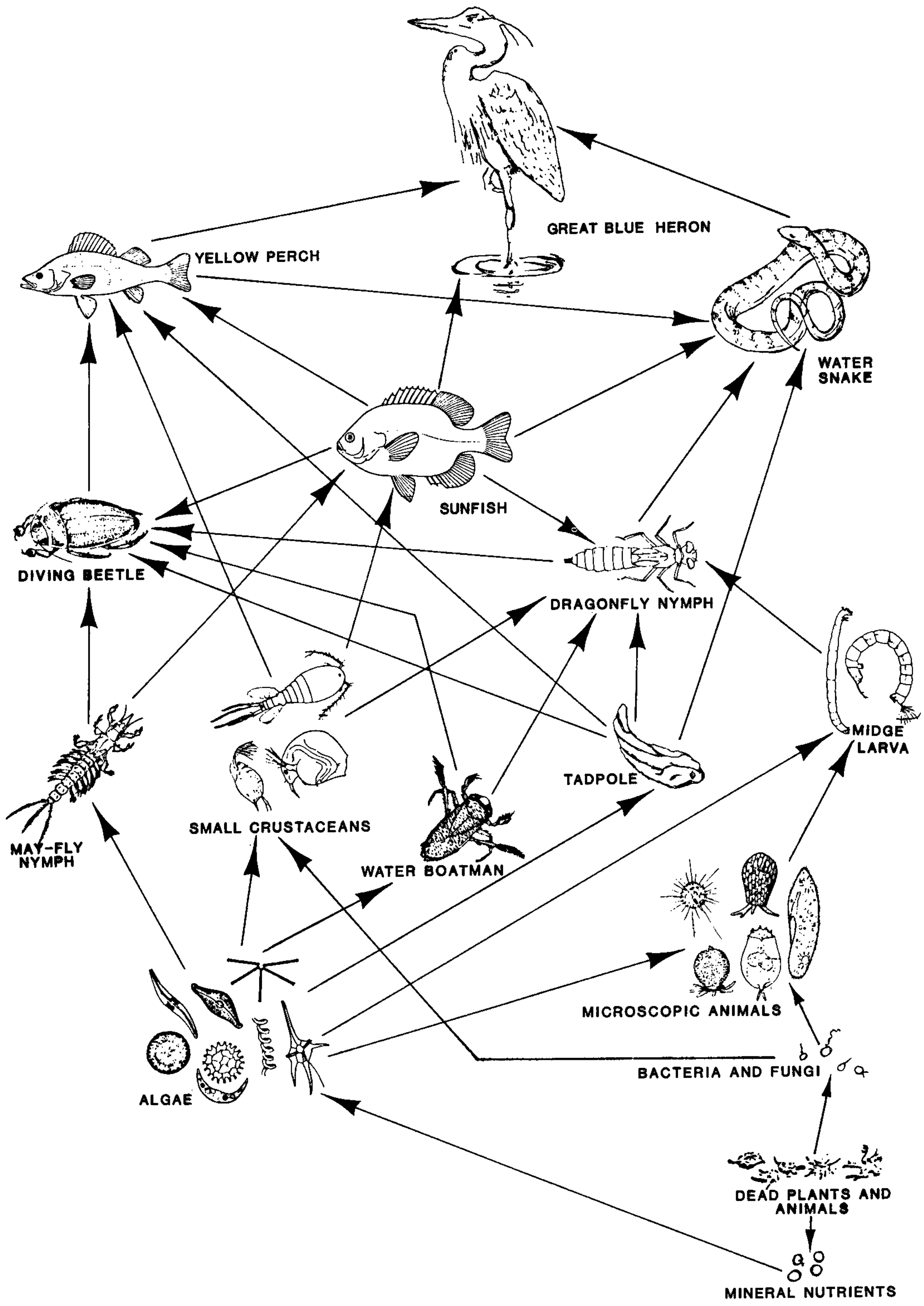

Figure 41. Food chain of the great blue heron (Ardea herodias) in Lake St. Clair (U.S. Army Corps of Engineers 1974).

County, Michigan wetlands have sustained yield of 16 muskrats/hectare. This is a relatively high yield for coastal wetlands which usually range from 5 to 15/hectare. The food supply of these omnivorous herbivores may be diverse, especially during periods of stress. Baumgartner (1942) has identified 34 food items for muskrats in Michigan. The preferred food is cattail, bulrush, and bluejoint grass. These emergent plants are common in Lake St. Clair wetlands.

Little site specific research has been conducted on Lake St. Clair muskrats, but work done on this species in western Lake Erie can provide some insight. Several structures observed in Lake Erie coastal marshes are associated with the activity of muskrats (Bednarik 1956). The most noticeable structure is the muskrat "house", a dome-shaped pile of emergent vegetation, primarily cattail (Figure 42). The average house varies in size from 1 to 2.5 m in diameter at the base and from 0.7 to 3 m in height. They are located in stands of emergent vegetation or along the periphery of such stands. They are often constructed on protuberances in the marsh bottom, utilizing plants in the immediate area. The majority of houses are constructed during the fall, chiefly from October to November. Building activity occurs mainly during periods of darkness. Typical densities of active muskrat houses in Sandusky Bay marshes average 4/hectare. Small houses have one living chamber and larger houses have two or three living chambers above the water line. The living chamber is about 35 to 50 cm in height and is formed by the muskrat chewing out the vegetation. Most houses have two underwater exits or plunge holes.

Figure 42. Muskrat "houses" in a well-populated section of Magee Marsh, western Lake Erie, Ohio (Bednarik 1956).

Other structures made by muskrats are associated with feeding activity. Rafts are constructed from stems of plants piled in a circular fashion to serve as a feeding platform. "Feeding bogs" are covered, floating platforms which are smaller in dimensions than the muskrat house and are no higher than 40 cm, averaging 60 cm in diameter. These structures are usually located some distance from the larger muskrat house and serve as protected feeding sites. "Push-ups" are built only in the winter and are small, hollow, dome-shaped shells of submergent vegetation over a plunge hole in the ice. These protected plunge holes allow the muskrat to extend the area over which it can forage since it can travel greater distances under the ice.

The reproductive cycle of the muskrat on Sandusky Bay of Lake Erie has been documented by Bednarik (1956) and Donohoe (1966). Reproductive activity begins in January and ends in September, with the greatest activity occurring in February and March. The time of first mating is determined in part by the time of ice breakup. The gestation period varies from 20 to 28 days. Females usually have two litters of young per season although some may have three litters. Placental scar counts indicate that the mean number of young per litter is 11, but Bednarik concluded that at the time of birth, the average litter size is eight. Sandusky Bay has habitats similar to those of Lake St. Clair and is located on the south shore of Lake Erie approximately 100 km southeast of Detroit.

Predation by mink occurs but is not an important influence on the muskrat population because of the low numbers of mink in the marshes. Predation on juvenile muskrats by raccoons and Norway rats occurs in early summer and is not an important mortality factor. Some mortality is attributed to hemorrhagic or "Errington's" disease. This disease can cause significant fluctuations in the muskrat populations in western Lake Erie marshes (Bednarik 1956) and presumably also in Lake St. Clair marshes.

The annual harvest of muskrat in the Michigan counties and Ontario areas bordering Lake St. Clair is given in Table 24. The harvest from Michigan and Ontario marshes can exceed 100,000 individuals per year. With a pelt plus carcass price of approximately $10.00 per animal, muskrat trapping is a million dollar a year industry in the Lake St. Clair region. Jaworski and Raphael (1978) observed that furs from the coastal wetlands are of high quality, hence the fur prices in these areas are usually high. The recent decline in Ontario production is attributed to roughly a 30% decline in wetland area during the same period (G. Duckworth, Ontario Ministry of Natural Resources; pers. comm.)

Table 24. Muskrat harvest in Michigan and Ontario bordering Lake St. Clair and connecting waterways.[a]

Year	Michigan counties: St. Clair	Macomb	Wayne	Total
1965	2,675	1,272	112	4,059
1966	15,515	4,084	2,700	22,299
1967	24,335	2,658	392	27,385
1968	13,395	5,469	1,006	19,870
1969	16,063	6,012	1,484	23,559
1970	30,350	3,479	1,149	34,978
Annual mean	17,055	3,829	1,141	22,025

Year	Ontario Areas: Dover Twnshp.	Walpole Is.	Total
1974	23,512	67,880	91,392
1975	22,591	73,796	96,387
1976	21,174	31,212	52,386
1977	17,174	14,790	31,964
1978	11,658	15,385	27,043
1979	12,715	37,340	50,055
1980	15,138	26,891	42,029
1981	8,886	26,363	35,249
1982	9,215	29,780	38,995
Annual mean	15,785	35,937	51,722

[a]Data sources: Jaworski and Raphael (1978) and George Duckworth, Ontario Ministry of Natural Resources (pers. comm.).

Raccoons

Again, little direct information is available on the ecology of raccoons in Lake St. Clair wetlands, but western Lake Erie studies can be helpful in understanding this animal. Several aspects of the life history of the raccoon in Sandusky Bay marshes were investigated by a trapping and telemetry study (Urban 1968, 1970). The density of the raccoon population was estimated to be 17/km^2. The juvenile to adult female ratio was 1.2:1.0, indicating a moderate productivity for the raccoon population. The mean weights of both adults and juveniles increased from spring until early winter and then decreased over the winter.

The telemetry portion of the study provided information on raccoon movements, home range, and denning. Generally, raccoons spend the daytime period in or near dens. The amount of nocturnal movement is related to the size of the home range. Raccoons with larger home ranges move greater distances. Raccoons move at a mean rate of 162 m/hr. Marshland is the major habitat type encompassed in an average night of travel and the habitat type in which raccoons spend the most time. Raccoons spend approximately 73% of the time in the vicinity of shallow water (Figure 43). Male juvenile raccoons disperse from the marsh in the fall.

Raccoons do not appear to search out waterfowl nests, since little change occurs in their movement patterns when waterfowl nesting is initiated. Dikes receive high usage in proportion to the amount of area they represent in the marsh. Movements of female raccoons encompass more wooded area per night than the male raccoons. Home range for the average raccoon is 51 hectares in size.

Food items of raccoons in Sandusky Bay marshes (Lake Erie) include muskrat, crayfish, fish, duck eggs, plant material, seeds, and birds (Andrews 1952, Bednarik 1956, Urban 1968). Fish, crayfish, and plant material were the chief food items

Figure 43. Raccoon (Procyon lotor), a common predator of duck nests in Lake St. Clair wetlands.

in all seasons. Muskrat fur was found in only 8% of raccoon scats collected year round, but in 47% of scats collected in the spring. Andrews (1952) noted that chimney crayfish (Cambarus limosum) is a favorite food of raccoons in the summer. Raccoons were responsible for the termination of 39% of the waterfowl nests built on the Sandusky Bay dikes in 1967 and 1968 (Urban 1970).

Raccoons are the most significant furbearer in the Lake St. Clair wetlands in terms of pelt value of the total harvest. The density of raccoons in Lake St. Clair wetlands has been estimated at about 0.3/hectare by Jaworski and Raphael (1978). They indicate a value per pelt plus carcass of about $40.00 for the early to middle 1970s. Therefore, the 38,000 hectares of wetlands within the study area has a total raccoon value of about $456,000.

CHAPTER 4. ECOLOGICAL PROCESSES

4.1 ORIGIN AND EVOLUTION OF LAKE ST. CLAIR WETLANDS

The relationship of water levels, topography and the geomorphic development of the Lake St. Clair coastal zone is significant to biogeographical development and maintenance of the wetlands and their areal development. This is particularly true for the St. Clair Delta, which is constantly changing its morphology. Because of shifting channels, variable flow regimes, and sedimentation, the geological nature, (and hence the biological characteristic of the littoral zone and wetlands) has not been constant.

Since not all rivers which debouch into a basin deposit deltas, the marine processes are significant. A delta is not solely a product of river deposition. Basically, deltaic landforms are a product of both river and marine processes. The river contributes the sediments to the receiving basin. Whether the sediments accumulate in the mouth is dependent upon the marine processes such as wave action and long-shore currents, and the geomorphic character of the submarine topography. If there is a dominance of the marine process the sediments may be transported down coast and a delta may not be extensive. Conversely, a river dominated system contributing an excess of sediment coupled with a low wave climate will promote deltaic development.

Several of our concepts of delta development have been obtained from the Mississippi deltaic plain. Because of oil and gas exploration, river and marine commerce, and the extensive wetlands in the area, the Mississippi River Delta has been extensively studied geologically, biologically, and geographically. It serves as a model by which other marine and lacustrine deltas are compared.

Physical Uniqueness of the St. Clair Delta

Traditionally deltas have been classified on the basis of their morphology and descriptive terms such as arcuate, bird-foot, and cuspate have been applied to the various delta shapes. Using this classification the St. Clair, like the Mississippi Delta may be described as bird-foot. It is generally assumed that a given set of processes is responsible for each deltaic morphology. Although, morphological similarities are evident, significant differences also occur (Table 25).

A unique aspect of a delta's geomorphology is related to its changing base levels. The base level of all marine deltas appears to have been eustatically stable over the past 4,000 years. In the Mississippi Delta, because of the stable sea level, the ancestral streams deposited a series of delta lobes along the Louisiana coast. At Lake St. Clair, changing base levels have produced two distinct deltas at different levels, the premodern and the modern. Examples of this base level change are apparently rare with regard to deltaic deposition.

Marine deltas are often characterized by subsidence due to sediment loading. Geosynclinal downwarping and sediment compaction in response to sediment accumulation in the Mississippi Delta has allowed up to 122 m of deltaic deposits to accumulate since the termination of the Late Wisconsin glacial ice (Morgan 1970). With continued sedimentation and subsidence, the shifting delta lobes overlapped, burying older deltaic environments. Therefore, the traditional sedimentological units, top-set, fore-set,

Table 25. Factors influencing lake and marine delta morphology.[a]

Factors	Characteristics	St. Clair Delta	Mississippi Delta
Geomorphic:	Base level	Long- and short-term variations	Stable
	Flow regime	Seasonally constant	Seasonally variable
	Channel diversion	Downstream (spring ice jams)	Within alluvial valley (spring floods)
	Structural behavior of basin of deposition	Stable	Sediment compaction and significant subsidence
	Dominant sediment size	Fine to coarse sand	Clay to silt
	Relative rate of sedimentation	Slow	Rapid
Marine:	Relative wave energy	Low	Low
	Offshore profile	Flat to gently sloping	Flat to gently sloping
Vegetative:	Vegetation zonation	Deciduous trees to freshwater marsh	Predominantly fresh to brackish to salt marsh
	Control of vegetation distribution	Short-term lake level changes	Salinity, substrate composition, and tidal range

[a]Data source: Jaworski and Raphael (1973).

and bottom-set beds, identified on the margins of Lake Bonneville by Gilbert (1890) do not occur in the Mississippi Delta complex.

Subsurface data reveal that the St. Clair Delta is stable. Sediments accumulating in the delta are not of sufficient thickness to allow any significant downwarping to occur. Borings on several beaches suggest that the base of these depositional features is at approximately low water datum. Apparently the beaches have not subsided as the cheniers have done on the flanks of the Mississippi Delta.

Isostatic rebound in the St. Clair basin, due to the waning of Wisconsin ice following the Valders maximum some 10,500 to 12,500 years ago, has been minimal. Pertinent zero isobases since the Valders maximum ice advance are the Algonquin and Nipissing hinge lines, which are oriented east-west and located in the central portion of Lake Huron. Therefore, crustal displacement due to regional glacial rebound or localized sedimentation does not appear to have directly influenced the vertical and horizontal morphology of the St. Clair Delta. The St. Clair Delta has, in fact, extended itself across an essentially rigid platform.

Although structural stability and minimum subsidence characterize the St. Clair Delta, significant changes in the level of Lake St. Clair in the past few millenia have contributed to the morphology of the delta. Based upon a structural framework, deltas may be deposited in one of three geologic environments: a subsiding area, a stable area, or an elevating area. The Mississippi Delta with its thick accumulation of recent sediments, is a classic example of a subsiding delta. Although the Lake St. Clair basin is geologically stable, the effect of a lower lake level on the delta complex is similar to elevating the land. Since base level in Lake St. Clair has dropped in the last 4,000 years, the focus of depostion has shifted lakeward creating the modern St. Clair Delta and wetland habitat.

The configuration of deltas is related to offshore slope, relative wave power in the nearshore zone, and riverine influence (Wright and Coleman 1972). A delta such as the Mississippi with its digital distributaries and marshy embayments is dominated by its river since its offshore slope is flat to convex and the nearshore wave power is low. Although long-term wave data have not been recorded for Lake St. Clair, wave energy must be considered to be low since the maximum fetch for wave generation for the delta is only 40 km. The subaqueous delta front is shallow and concave, causing waves generated in the shallow lake to attenuate lakeward of the delta. Also, marshes have become established on exposed offshore areas between Johnson Bay and the -2 m contour suggesting that low wave energy conditions prevail. Although there may be an occasional dominance of marine processes as evidenced by the presence of transgressive beaches, it must be concluded that the geometry of the St. Clair Delta, like that of the Mississippi, is principally dictated by its river.

Morphological Settings of Lake St. Clair Wetlands

The previous discussion suggests that although the St. Clair and Mississippi river deltas have similar appearances several dissimilar features and processes prevail. For example, the dominant sediment size in the Mississippi Delta is silt to clay, whereas, the St. Clair Delta is fine to coarse sand. Also, the relative rate of sedimentation in the St. Clair Delta is slow compared to the rapid rate of the Mississippi Delta. The wetlands discussed in this community profile exhibit a diversity of form. However, their distribution can be related to fundamental geomorphic features some of which are unique. Jaworski et al. (1979) examined and developed geomorphic models for the coastal wetlands of the Great Lakes as a step to understanding their origin, stability, and distribution.

The occurrence, distribution, and diversity of coastal wetlands are, in part, determined by the morphology of coastal Lake St. Clair. Perhaps in no other biogeographic environment is the relationship between landforms and vegetation so evident. All wetlands occur in topographical depressions created by nature or more recently by humans. These topographical lows may be erosional in origin such as river channels or depositional in origin such as lagoons or floodbasins.

Although elevations of the St. Clair Delta are low, a diversity of landforms exists (Section 2.1) . When the entire shoreline of Lake St. Clair is considered, the habitat diversity is even greater. Twelve wetland settings have been identified in Lake St. Clair (Figure 44). All but one setting (i.e., diked/disturbed) are of a natural origin. The St. Clair Delta exhibits a greater diversity of wetland settings because it is a product of river as well as marine processes. The habitats beyond the deltaic plain are fewer in number but unique to the lake shoreline. A third suite of wetland habitats occurs both in the delta complex and on the shoreline.

The following section discusses the 12 wetland habitats recognized in Lake St. Clair. The deltaic habitats are described first followed by the coastal environments of wetland occurrence. Finally, wetlands occurring in both the St. Clair deltaic and coastal plains are described:

1. River shoulders are shallow submerged features of the distributary channels

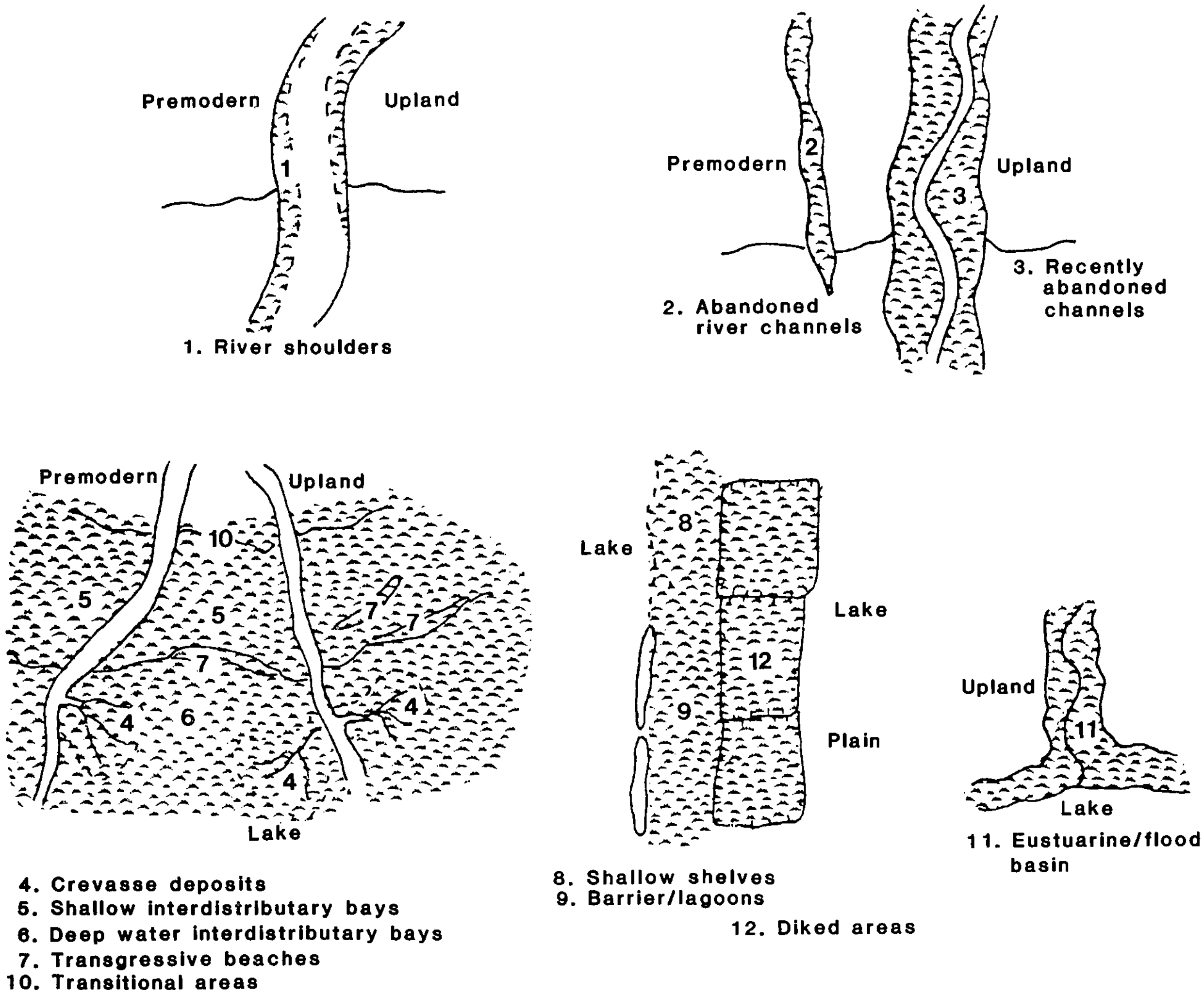

Figure 44. Twelve wetland habitats recognized in Lake St. Clair.

of the St. Clair Delta. Paralleling the shoreline of the channels, the submerged river shoals extend 35 m into the river and have maximum depths of 2 m. The sediment consists of fine sand. The feature is reasonably continuous along the length of the channels but is normally absent on the outside or cutbank side of the channel. The feature attains a maximum width at submerged point bars. At the channel shoreline, reeds such as the robust Phragmites australis are dense (Figure 29); however, submergent aquatics are dominant. An aggressive invader, Eurasian water-milfoil has become more abundant in the last decade in the distributary channels (Schloesser and Manny 1982). It appears to be a common submersed macrophyte and a minor nuisance to recreational boating in the delta region as well as in Anchor Bay. Furthermore, the plant density appears to be greater in the non-commercial navigation channels (i.e., North and Middle channels).

2. Abandoned river channels dissect the upland surface of the delta and merge into the modern delta when traced lakeward. The channels are long and linear and of variable width. The largest channel on Dickinson Island is some 500 m wide, but usual channel widths are about 100 m. The sediments have a fine texture and a high organic

content suggesting gradual decay over time. The boundary between the premodern delta upland and the abandoned channel is usually distinct especially at the apex of the delta. During years of low lake level several of the ancient channels are above the water table and plant stress may occur. Emergents such as hard-stem bulrush (Scirpus acutus), arrowhead (Sagittaria latifolia), and three-square (Scirpus americanus) colonize the deeper water of the channels (1 m) as do water lilies and occasionally buttonbush (Cephalanthus occidentalis).

3. Recently abandoned channels are generally similar to the abandoned channels discussed except that they are still in the process of decay. Chematogen Channel is a distributary channel which continues to conduct St. Clair River water to Lake St. Clair. These channels are mainly on the Ontario side of the delta and were responsible for the deposition of the Canadian portion of the delta. Since that time this area was abandoned and the more recent depositional activity began in Michigan. As abandonment occurred, the channels were gradually silted so that only narrow distributaries remain today. Such channels not only dissect the premodern delta but the modern surface as well. The sediment of the channel fills is fine sand, but some silts have been deposited from the adjacent lake plains as well. Since these channels occur on the modern delta, slopes are more gentle. In contrast abandoned river channels are on the premodern surface and slopes to the channels more distinct. The channel fills of the recently abandoned channels are often submerged beneath 15 cm of water and colonized by sedges (Carex spp.) and more sporadically by blue-joint grass (Calamagrostis canadensis). A variety of submersed aquatics such as Chara spp. and pondweeds (e.g., curly pondweed Potamogeton crispus) colonize the narrowing active channels.

4. Crevasse deposits occur on the flanks of distributary bays and have a lobate form. Since they are flood or higher energy deposits they are composed of coarser sand. Channel depths are approximately 4 m and are not colonized, but the sand deposits adjacent to the "highways" support communities of bulrush (Scirpus spp.). Most crevasse deposits are at the lower end of the active distributary channels and thus exposed to wave action. Because of higher wave energies and perhaps due to ice damage and recreational boating the emergent aquatics are not particularly dense. The landward side of the crevasse deposits appear to be better protected from wave action and thus support a denser stand of emergent vegetation including not only bulrush in deeper habitats but cattails (Typha spp.) in shallower areas of the deposit. Also crevasse deposits closer to Lake St. Clair (farther down the distributary channels) are exposed to greater wave action and are sparsely colonized with bulrush.

5. Shallow interdistributary bays occupy extensive areas between the open lake and the equally obvious higher premodern deltas. On the flanks these shallow wetland habitats are bordered by natural levees. Occasionally, particularly in Michigan, narrow discontinuous beaches occur. The sediment in the bays was derived from crevasses during high water periods and are thus silty-sand size particles and mostly mineral in character. Organic sediments are sparse and discontinuous. At the surface the organic accumulation, where present, ranges in thickness from 5 to 15 cm. Water depths average 5 to 30 cm. The shallow interdistributary bays are almost exclusively colonized by dense stands of cattails of which the hybrid Typha x glauca standing 2 to 3 m high dominates. At slightly higher elevations sedges are interspersed with cattails. The high cattail productivity and the low organic accumulation suggests that these habitats are flushed during high water periods. The sedimentation process is relatively complete throughout the deltaic plain, though a few small lakes (e.g., Goose Lake) still persist.

6. Deep water interdistributary bays are located lakeward of the shallow

interdistributary bays. The landward side is bordered by low, poorly developed transgressive beaches. Their flanks are characterized by slightly higher, poorly developed natural levees which are permanently breached by crevasse channels. Lakeward these bays are exposed to wave action of the open lake. As clastic sediments are introduced into these bays, the basins will evolve into shallow interdistributary bays. Water depths range from 0.5 to 1.75 m and the bay bottom consists of fine sand. Occasionally in sheltered areas silt deposits will accumulate, but organic deposits are sparse through the habitat. Wave action prohibits the colonization of dense emergents; however, Scirpus spp. are prevalent. The deep water bays are confined to the Michigan portion of the delta where the distributary channels are most active and where natural levees extend into Lake St. Clair. Common submersed aquatics include Characeae and Najas flexilis (Schloesser and Manny 1982). The distribution of submersed macrophytes may be due to a lack of suitable substrate for attachment or excessive wave action.

7. Transgressive beach deposits are best developed within the St. Clair Delta but do sporadically occur along the Ontario shoreline. The beaches are wave deposited features standing approximately 30 cm above the lake. As noted in Figure 4, older beach deposits occur landward of the active transgressive beach in the shallow interdistributary bays. They are composed of stratified coarse sand, gravel and organic debris. Although they vary in width, most beaches are about 5 m wide. Borings through the beach deposits reveal alternating layers of coarse clastics and thin (1 cm) wave deposited organic lenses. This clearly suggests that the features were deposited during periods of erosion. During higher wave energy conditions the beaches are not breached; but rather overwash occurs, causing rafted debris to be deposited atop the shallow interdistributary marsh. Woody vegetation including eastern cottonwood (Populas deltoides), willows (Salix spp.) and staghorn sumac (Rhus typhina) colonize the beaches. During higher water years sedges (Carex stricta), reed-canary grass (Phalaris arundinacea), and jewelweed (Impatiens spp.) commonly colonize the beaches. The latter three species are more common on the overwash deposits landward of the beaches.

8. Shallow shelf environments border the nearshore zone of most of Lake St. Clair. The shelves are composed of silt-sized clastic fragments. The shelves are approximately 200 m wide, 1.5 m in depth and are turbid especially following storms. Wetlands colonizing this habitat exist as a low dense fringe parallel to the shore and remain exposed to lake effects such as wave action. This habitat is best displayed along the eastern shore of the lake and is colonized with emergents and submergents. The dominant vegetation is emergent macrophytes such as cattail. Other wetland species include lake sedge (Carex lacustris), large stands of pickerel weed (Pontederia cordata), water-milfoil (Myriophyllum heterophyllum), and white water lily (Nymphaea odorata) (Mudroch 1981).

9. Barrier/lagoon complexes occur south of Mitchell Bay along the eastern shoreline of Lake St. Clair. The barriers are poorly developed and stand approximately 50 cm above the lake. However, they do provide some protection from wave action and seiches, especially during lower water years. The lagoon is approximately 1,000 m in width and is characterized by a silty bottom. Morphologically this habitat is similar to the shallow shelf environment except for the occurrence of a low barrier. The bottom sediments not only include silts but loose, partially decomposed organic fragments which may be in situ or may have been transported into the lagoon by streams from the adjacent lake plain. Emergent macrophytes dominated by cattails (Typha latifolia) occur in the area. The landward side of these wetlands has a gentle natural slope which in most instances along Lake St. Clair is abruptly terminated by

artificial dikes. It is important to note that the Ontario shoreline north of the Thames River has not experienced significant coastal recession in recent years (Boulden 1975) whereas the south shore of the lake has. This suggests that the barrier and adjacent wetlands retard wave action on this coastal reach.

10. Transitional areas are broad zones separating perennial wetlands from well-drained upland surfaces. In some instances, such as on Harsens Island and along the eastern shoreline of Lake St. Clair, the transitional areas have been incorporated in diked farmland or water level-controlled wetlands and thus do not exist. However, good but rather isolated examples occur on Dickinson Island and east of St. John's Marsh in Michigan. The sediments consist of fibrous peat macrofragments which are underlain by fine, mottled sand. The transition zone is normally not permanently flooded and water tables are about 15 to 30 cm below the surface. The lakeward side of this environment is characterized by sedge tussocks (*Carex* spp.) interspersed with sparse cattails. Where water tables are deeper, the transition zone is colonized by a meadow which includes but is not limited to red osier dogwood (*Cornus stolonifera*), gray dogwood (*C. racemosa*), panic grass (*Panicum* spp.), and bluejoint grass. On the landward margin trembling aspen (*Populus tremuloides*) is abundant. Because of the variable elevation and depth to groundwater this zone exhibits a diversity of wetland plants. Similar wetland species have been observed on the premodern surface of the St. Clair Delta. Here local depressions are underlain by clay pan which results in a perched water table which commonly supports dogwood/meadow vegetation.

11. Estuarine/floodbasin habitats are characterized by marsh vegetation bordering a river which debouches into the lake. The Clinton River and several small streams tributary to Lake St. Clair support such wetlands. The extent of the vegetated wetland is often restricted by a steep backslope paralleling the flood plain. The sediments are derived from flood events and are usually fine sand and silt with a significant organic content. Natural levees adjacent to the channel are poorly developed and vegetation zonation difficult to detect. The water level in this wetland habitat is variable and depends in part on the river discharge. During dry years the wetlands may be stressed because of a low water table. Therefore the wetland may be seasonal in nature. At the confluence of river and lake, water tables are most often at or very near the surface and the floodbasin will sustain dense emergents in most years. At the mouth of the Clinton River dense stands of cattails have been observed for many years. Upstream the marshes grade into bottomland swamps.

12. Diked wetlands are a cultural modification of a wetland rather than a physical entity. Included in this category are transitional zones which have been diked and drained for farming or recreational purposes. Since these wetlands transcend physical boundaries such as soil/sediment types and slopes, their morphological framework is less meaningful. On Harsens Island the Michigan Department of Natural Resources has diked and drained much of the shallow distributary bay area and the transition zone. The land cover of the central portion of the island is in corn and grain crops which are utilized as part of a waterfowl hunting management scheme. Walpole Island is the largest island in the delta. A large part of the island, which is now cultivated mainly for corn and soybean, was also a shallow interdisciplinary bay. The diked marshes along the east shore of Lake St. Clair have long been used for private duck hunting. Water level in these marshes is regulated by pumps, dikes, and canals. The marshes are landlocked and water depths range from 10 to 50 cm (Mudroch 1981). Emergents colonize these marshes. Dominant macrophytes are the cattail and sedge. Also large stands of pickerel weed, water milfoil (*Myriophyllum heterophyllum*), and white water lily occur in the channels within these diked wetlands.

Table 26 summarizes the identified morphological wetland settings in Lake St. Clair in terms of selected physical characteristics. For this investigation the coastal and deltaic wetlands are classified into four major vegetative zones:

1. Submergent (e.g., pondweeds, coontail)
2. Emergent (e.g., cattail, bulrush)
3. Sedge/meadow (e.g., sedge, canary grass)
4. Shrub (e.g., dogwood, willow, sweet gale).

Wetland diversity exhibited by submergent, sedge, and shrub vegetation is most evident in the abandoned channels (2) and the transitional (10) zones. Here, topography is variable, wave or river current action is low or not applicable and turbidity is low. Conversely the wetland community is less diverse along river shoulders (1), crevasse (4), and estuarine/flood basin (11) environments. These rather monotypic wetlands appear to be associated with higher wave/current action and higher turbidity levels. The exception is the shallow interdistributary bay (5) environment which is composed of dense and robust stands of cattails. Perhaps the combined periodic exposure and a higher organic content of the substrate account for the dominance of the emergents.

4.2 BIOLOGICAL PRODUCTION

Examination of energy flow in coastal wetlands shows that the entire heterotrophic component of the wetland is dependent on organic matter produced during photosynthesis. In many cases, utilization of the material is through grazing of living tissues. Many species of waterfowl feed on various parts of aquatic hydrophytes. The seeds of Potamogeton, Carex, Brasenia, Polygonum, Zizania, and Scirpus are preferred foods as well as foliage of Potamogeton, Najas, Vallisneria, Lemna, Elodea, and Chara, and tubers or rootstocks of wild celery (Vallisneria americana) and sago pondweed (Potamogeton pectinatus). Mammals such as muskrat, mice, and deer browse heavily on several species of aquatic hydrophytes. Phytophagous insects are the food supply for several species of birds, fishes, reptiles, and mammals (Tilton et al. 1978).

A more significant form of utilization is the direct consumption of detritus or alternatively, the microbial populations associated with organic particulate matter. Numerous invertebrates rely completely on these food sources. These organisms in turn form the food supply for fish, amphibians, reptiles, birds, and mammals.

In addition to plants being a direct or indirect food source for many species of animals, aquatic plants provide cover and nesting areas for waterfowl. Several species of fish, such as the northern pike (Esox lucius), spawn in vegetated wetland areas and muskrats (Ondatra zibethicus) prefer emergent vegetation for construction of feeding platforms and houses.

Nutrient Cycling

Nutrient cycling is important to the continuation of primary and secondary production in wetlands (Figure 45). Coastal wetland vegetation immobilizes certain amounts of nutrients, a portion of which are released upon senescence and decay of the plants. Depending on the sedimentation characteristics of the wetlands, nutrients are stored in the wetland as organic sediment or peat. In the marsh soils, microbial processes transform some of the nutrients from organic to inorganic forms. The net effect of these processes is generally a reduction in the concentration of nutrients in water flowing through the wetland. Therefore, the coastal marshes are important in controlling nutrient loading to nearshore waters of Lake St. Clair (Tilton et al. 1978).

Studies of metals uptake by aquatic plants provide some information on nutrient cycling. Mudroch and Capobianco (1978) studied the uptake of metals from the water and sediment by emergent, submersed, and floating-leaved plants in marshes along the Ontario shore of Lake St. Clair. They found that submersed

Table 26. Morphology and relative physical relationships of the Lake St. Clair wetlands.

Wetland environment	Substrate	Water depth[a] (m)	Dominant vegetation	Current/ wave action[b]	Turbidity
1. River shoulders	sand	-6.0	submergent	high/low	moderate
2. Abandoned river channels	silt/ organics	-1.0	emergent/ submergent/ sedge/scrub	low/NA	low
3. Recently abandoned channels	silt/ organics	-0.5	emergent/sedge	med/NA	high
4. Crevasse deposits	sand	-1.5	emergent	high/med	high
5. Shallow interdistributary bays	fine sand/ organics	-0.3	emergent	low/low	low
6. Deep water interdistributary bays	fine sand	-1.5	emergent/ submergent	high/high	high
7. Transgressive beach deposits	coarse sand/ organics	+0.5	sedge/scrub	low/high	NA
8. Shallow shelves	silt/clay	-1.0	emergent/ submergent	low/high	high
9. Barrier/lagoon complex	silt/clay	-1.0	emergent/ submergent	low/low	high
10. Transitional areas	fine sand	+0.3	emergent/ submergent	NA/NA	NA
11. Estuarine floodbasin	sand/silt	+0.2	emergent	high/NA	high
12. Diked areas	variable	-0.1	emergent/ submergent	low/low	moderate

[a] - Below level of lake
+ Feature usually above lake level.

[b] NA Not applicable.

plants accumulated the highest concentrations, considerably higher than the source water and sediment, and that these elements were retained in the plant tissues until decay processes incorporated them into surface sediments.

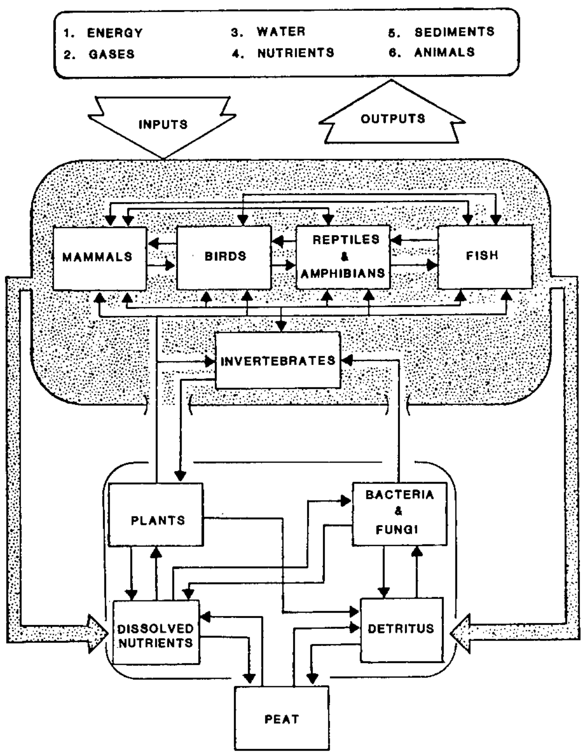

Figure 45. Cycling of energy and material through the Lake St. Clair coastal wetland ecosystem (Tilton et al. 1978).

Mudroch (1980) also studied the geochemical composition of sediment, uptake of nutrients and metals by macrophytes, and nutrient and metal composition in the water at Big Creek Marsh on the northeast shore of Lake Erie in Long Point Bay. The maximum concentrations of most metals (Pb, Ni, Ca, Cr, and Zn) in marsh sediments were lower than concentrations found in Lake Erie surficial muds, presumably due to uptake by the aquatic plants in the mud. Submerged plants (Chara sp., Myriophyllum sp., and Elodea sp.) accumulated larger quantities of Ca, Pb, Cu, Ni, Cr, and Cd than emergent plants (Typha spp.), but nutrient concentrations were relatively uniform for all species (Table 27). She found that the biomass production of the macrophytes in the marsh was related to the subhydric soil fertility as well as the nutrient content in the marshwater. She concluded that short-term supplies of nutrient-rich sewage to the surface subhydric soil layer can have a prolonged effect on macrophyte production by enrichment of the nutrient pool maintained in the perennial plant system.

Energy Flow

The flow of energy through a food chain is often represented by a pyramid which illustrates the quantitative relationships among the various trophic levels (Figure 46). Juday (1943) was one of the earliest investigators to introduce trophic levels concepts, developed the

Table 27. Concentrations of nutrients and metals in wetland plants at the stage of maximum development, Big Creek Marsh, Long Point, Ontario.[a]

Species	Dry weight (%)				Dry weight (ug/l)					
	K	N	P	Ca	Pb	Cu	Ni	Cr	Cd	Zn
Typha latifolia	1.1	1.7	0.2	0.8	4	3	6	3	<1	18
Elodea canadensis	1.6	1.1	0.4	20.0	32	10	18	15	3	18
Nuphar advena	1.1	2.0	0.3	1.0	5	3	2	4	<1	18
Myriophyllum heterophyllum	1.2	1.8	0.3	4.4	27	6	15	8	2	15
Nymphaea odorata	1.0	1.8	0.2	0.9	7	3	3	4	<1	14
Chara vulgaris	1.7	0.8	0.1	19.5	32	9	17	10	2	14

[a]Data source: Mudroch (1980).

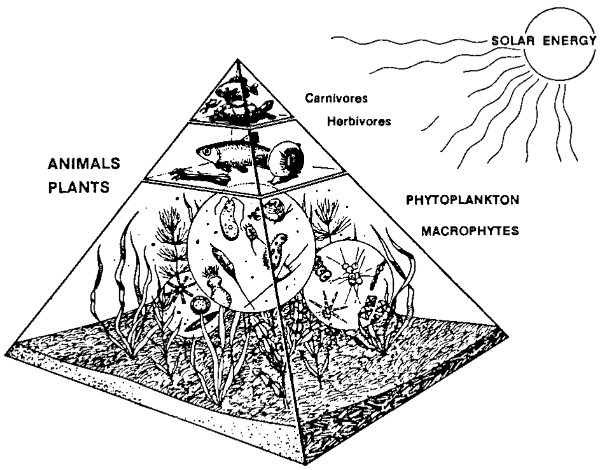

Figure 46. Energy pyramid in Lake St. Clair coastal marshes (Upper Great Lakes Regional Commission).

concept from studies of freshwater wetlands. He determined the various components of the aquatic population in Weber Lake, Wisconsin, as they existed in midsummer. The dissolved organic matter composed about 60% of the total pyramid, the fish, only 0.5%, and the other animals slightly less than 5% of the total.

In coastal marshes there are often four major sources of energy for aquatic consumers: 1) marsh detritus, 2) phytoplankton production, 3) detritus from terrestrial sources brought in by drainage and, 4) planktonic material carried into the marsh from the open lake. Although much research remains to be done on food chain production and ecosystem energy relationships, particularly of freshwater wetlands, there are a few general principles which appear to have validity: 1) food cycles rarely have more than five trophic levels, 2) the greater the separation of an organism from the basic source of energy (solar radiation), the less the chance that it will depend solely upon the preceding trophic level for energy, 3) at successively higher levels in the food cycle, consumers seem to be progressively more efficient in the utilization of food supply, and 4) in wetland succession, productivity and photosynthetic efficiency increase from oligotrophy to eutrophy and then decline as the marsh undergoes senescence (Jaworski et al. 1977).

Although no specific works have been published on the intricate structure of energy flow in Great Lakes coastal wetlands, Tilton et al. (1978) have generalized the important processes based on studies in other wetlands. The conversion of solar energy into biomass by autotrophs is perhaps the most important process. Conversion into a form available to heterotrophic organisms serves as the foundation for several complex and dynamic food webs.

The coastal wetland community possesses two basic complexes of interrelationships: 1) invertebrates (primarily insects), fishes, birds, and mammals which utilize living plant tissues and 2) organisms which utilize detritus or dead plant tissues. Living plant tissue (i.e., algae, Phragmites leaves, and Typha rhizomes) serve as food for phytophagous animals such as stem boring and leaf mining insects as well as certain aphids and beetles. Many species of waterfowl graze extensively on plant material, and muskrats are important plant consumers. The next higher trophic level in the first complex consists of animals which prey upon the phytophagous organisms. Spiders, predatory beetles, dragonflies, certain fishes, frogs, birds, and small insectivorous mammals are important organisms of this upper trophic level.

The second complex consists of a vast number of insect larvae which rely on organic detritus as a direct energy source or by stripping microbial populations from the surface of organic particles. Gastropods and annelids are also important organisms in the detritophagous complex. Whatever residual that is not utilized by these animals is subjected to further decomposition by bacterial and fungal populations. As with the phytophagous complex, there exists in the detritophagous complex a wide spectrum of animals which prey on the detritus-feeding organisms. Several species of insects, amphibians, waterfowl, and mammals compose this level, and many of these species are not selective in their prey, utilizing organisms from both complexes.

Teal (1962) found that a smaller percentage of the total energy represented in the primary production of wetlands

passes through the phytophagous complex than the detritophagous complex. Submergent vegetation tends to be inhabited and grazed more heavily than emergent forms (Krecker 1939) because the submergent aquatic macrophytes lack the more impenetrable structural tissues prevalent in the emergent type. Estimates of the proportion of material processed through each complex (Tilton et al. 1978), favors the detritus web (80% to 95%) over the grazing web (5% to 20%). Tilton et al. (1978) also point out that the importance of an organism to an ecosystem may exceed its role in energy flow. Muskrats utilize only a fraction of the available energy stored in the live plants they cut and harvest in the wetlands, but they may be of significant value to the detritophagous complex. Similarly, the teeming populations of phytophagous insects may consume only a small fraction of plant tissue, but through this activity may reduce the growth of host plants and the primary production of the wetland ecosystem.

Energy Budget

The energy budget for cattail (*Typha* sp.) marshes in Minnesota has been investigated by Bray (1962) and may provide insight for Lake St. Clair wetlands. During the growing season the distribution of the various components of solar radiation energy was as follows:

Component	Percent
albedo (reflection)	22.0
evapotranspiration	38.4
conduction-convection	38.5
primary production	1.1

This apparently low utilization of solar radiation by *Typha* sp. is consistent with other wetland studies and supports the general view that most plant communities utilize only 1% to 2% of the total solar energy for primary production (Tilton et al. 1978). *Phragmites* sp. in Austrian wetlands ranges from 1.2% to 2.0% for May through July (Sieghardt 1973) and *Spartina* sp. in Georgian estuaries utilizes 1.4% of total solar radiation (Teal 1962). The uniformity of these results suggests that emergent wetlands in the Lake St. Clair system utilize approximately 1.2% of solar radiation for primary production.

Emergent Macrophytes

Emergent wetland communities are among the most productive areas on earth. Westlake (1963) estimated that freshwater emergent macrophytes have a net primary productivity of 3,000 to 8,500 g/m^2/yr comparable in productivity to salt marshes and tropical rain forests. Productivity of freshwater submerged macrophytes ranges from 400 to 2,000 g/m^2/yr, less than half of their marine counterpart. Site specific primary productivity studies of coastal emergent wetlands in Lake St. Clair do not exist. Table 28 lists the maximum biomass and productivity of several emergent species (common in Lake St. Clair) for other areas of the Great Lakes region. Extrapolation of these data to the cattail marshes of Lake St. Clair can provide an approximate and reasonable estimate of productivity. *Typha* marshes appear to be one of the most productive communities, yielding values (approximately 2,500 g/m^2/yr) near the lower end of the range expected for freshwater emergent macrophytes.

Submersed Macrophytes

Lake St. Clair, particularly Anchor Bay and Mitchell Bay, are known for their well developed submerged aquatic macrophyte beds. Dawson (1975) found that considerable spatial variation in standing crop exists in Lake St. Clair bays (Table 29). He estimated mean dry weights of various submerged communities to range from 4 g/m^2 in shallow areas characterized by sparse cover of stonewort (*Chara* sp.) to 316 g/m^2 in areas dominated by dense growths of water-milfoil (*Myriophyllum spicatum*). Schloesser (1982) studied the monthly abundance of submersed macrophytes in the St. Clair River and Lake St. Clair during the 1978 growing season (Table 30). He found that the amount of submersed vegetation was low in early spring. No vegetation was found at the mouth of the Clinton River or the head of the Detroit River (Belle Isle) in April or May, and the only vegetation collected at Stag Island, Algonac and Anchor Bay during these months consisted of decaying or dormant material from the previous growing

Table 28. Biomass and productivity of emergent wetland plants of the Great Lakes region.[a]

Species	Common name	Maximum biomass (g/m²)	Net production (g/m²/yr)
Typha latifolia	broad-leaved cattail	1,360	2,456
Typha × glauca	hybrid cattail	4,000	1,440
Sparganium eurycarpum	giant bur reed	1,950	--
Sagittaria latifolia	common arrowhead	230	--
Glyceria grandis	manna grass	4,800	--
Phragmites communis	reed grass	2,695	--
Zizania aquatica	wild rice	550	630
Eleocharis sp.	spike-rush	185	--
Carex lacustris	lake sedge	1,400	1,186
Carex rostrata	beaked sedge	850	740
Scirpus fluviatilis	river bulrush	--	1,530
Scirpus validus	great bulrush	2,080	--
Juncus effusus	soft rush	1,745	--
	Mean	1,820	1,330

[a]Data source: Tilton et al. (1978).

Table 29. Estimates of standing crop biomass for submergent vegetation in Anchor Bay, Lake St. Clair (September, October 1974).[a]

Dominant taxa in community	Weedbed area (km2)	Range in dry weight (g/m2)	Percent of submergents
Chara	31.2	4-77	10.3
Chara-Najas	25.6	25	8.6
Potamogeton-Chara	13.7	65	11.8
Vallisneria-Myriophyllum	12.0	190	29.9
Chara-Nitella	9.9	37-247	11.0
Vallisneria americana	9.4	12-97	7.3
Myriophyllum	6.5	127-316	20.5
Heteranthera dubia	0.5	83	0.6
TOTAL	108.8	4-316	100.0

[a]Data source: Dawson (1975).

Table 30. Seasonal estimates of standing crop biomass for submersed macrophytes at several locations in the Lake St. Clair system (1978).[a]

Location	Dry weight (g/m2) June	July	Aug	Sept	Oct	Dominant taxa
St. Clair River (Stag Is.)	72	267	103	38	15	*Potamogeton* spp.
St. Clair Delta (Algonac)	54	97	158	174	284	*Potamogeton* spp. *Elodea canadensis*
Anchor Bay (Sand Is.)	85	113	135	133	146	*Myriophyllum spicatum*
Clinton River (mouth)	24	63	118	33	16	*Vallisneria americana*
Detroit River (Belle Isle)	0	38	52	38	17	*Vallisneria americana*

[a]Data source: Schloesser (1982).

season. By mid-June dominant plants sprouted new growth at stem and leaf nodes, and by mid-July new growth which did not originate from overwintering dormant material was found at all locations (Table 30). Higher maximum biomass values were generally observed at locations where dormant overwintering vegetation was observed in early spring. Figure 47 shows that the maximum biomass was reached in July in the St. Clair River (267g/m^2); in August in the Clinton River mouth (118 g/m^2) and Detroit River head (53 g/m^2); and in October in the St. Clair Delta (284 g/m^2) and Anchor Bay (146 g/m^2). The submersed macrophytes became senescent and the biomass values decreased by late fall at all locations. The results of this study indicated that little or no submersed macrophyte growth takes place before June or after October in the river or lake. The dominant taxa found at each location are given in Table 31.

4.3 COMMUNITY PROCESSES

Given the transitional or ecotone character of wetlands, the Lake St. Clair wetlands are even more dynamic due to the pulsing nature of the lake level changes and the connectivity due to the numerous distributary channels and embayments, particularly within the St. Clair Delta. By outlining the community processes in these dynamic and interrelated environments, the high primary and secondary productivity can be more fully understood.

The Lake St. Clair wetlands are actually composed of a variety of habitats including open ponds, cattail/reed marshes, earthen dikes, barrier beaches, delta flats, and wooded swamps. Collectively these habitats are known as the coastal marsh community. Each habitat attracts its own species of plants, birds, mammals, reptiles, amphibians, and in some cases, fish. The result is more variety in plant and animal life than in any other area of equal size in the interior of the bordering states and province. The overall conditions of the uncontrolled coastal marshes are still very primitive, some having been visited by no more than a handful of people in the last several decades. Within those marshes where natural processes are allowed to take place, zonation and succession in response to changing environmental conditions are

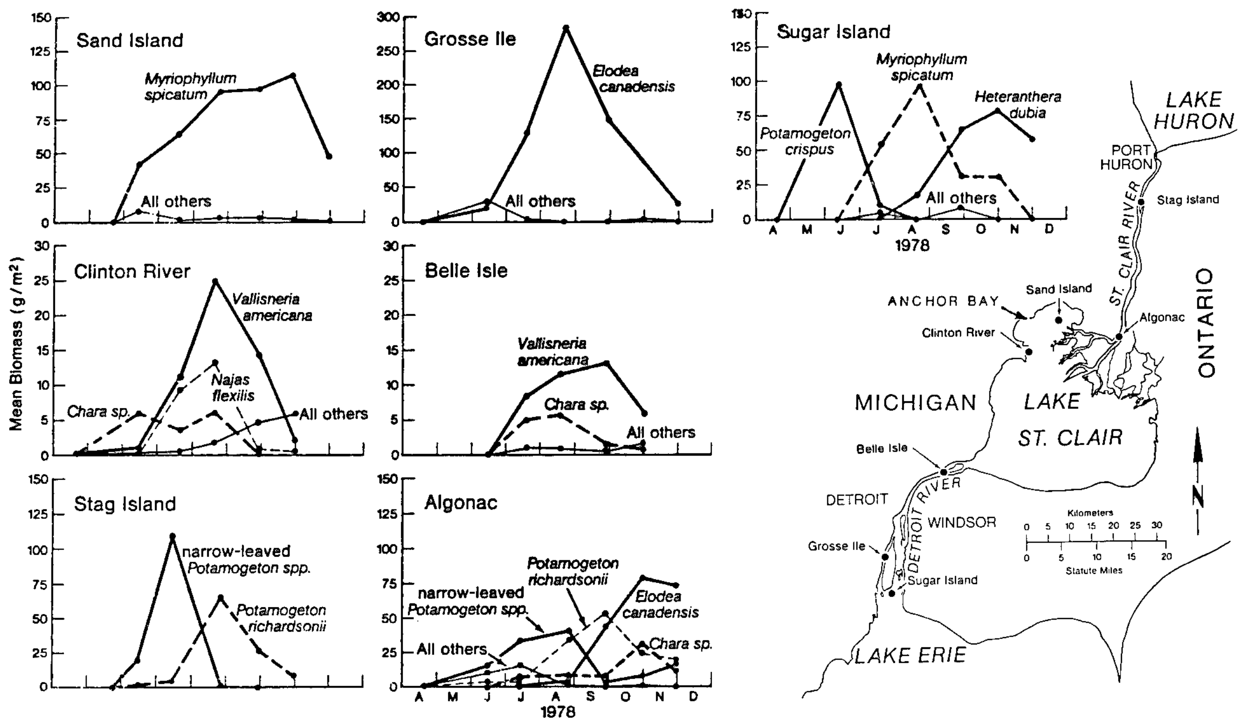

Figure 47. Seasonal growth (dry weight) of dominant submersed macrophytes in the St. Clair River-Lake St. Clair-Detroit River ecosystem (Schloesser 1982).

Table 31. Dominant submersed aquatic macrophyte taxa of the Lake St. Clair system.[a]

Taxa	St. Clair River (Stag Island)	St. Clair Delta (Algonac)	Lake St. Clair (Anchor Bay)	Clinton River (mouth)	Detroit River (Belle Isle)
Chara spp.		×	×	×	×
Elodea canadensis		×	×	×	×
Heteranthera dubia			×	×	
Myriophyllum spicatum			×	×	×
Najas flexilis			×	×	×
Potamogeton graminens	×	×			
Potamogeton richardsonii	×	×	×		
Potamogeton spp.	×	×	×	×	×
Vallisneria americana	×	×	×	×	

[a]Data sources: Dawson (1975), Schloesser (1982).

among the important community processes. Water level fluctuation, and the resultant plant and animal response, is often the most significant driving force.

Plant Zonation and Succession

Because the water level of Lake St. Clair is not stable, but has oscillated over 2 m during the period 1900 to 1977 (Jaworski et al. 1979), the wetland vegetation along the lake margins exhibits pulse stability. The concept of pulse stability implies that it is these water level fluctuations which result in the maintenance of the wetland communities. Thus, even though wetland plant communities retrogress during high lake level periods and shift lakeward during low water level conditions, these successional changes prevent the wetlands from being dominated by either aquatic or upland communities. Moreover, coastal wetlands do not become senescent or exhibit conversion to terrestrial environments as compared to inland, palustrine wetlands.

It is important to distinguish between annual (or seasonal) water level fluctuations and longer term oscillations. With regard to annual water level changes in Lake St. Clair, the average magnitude is approximately 0.5 m, with highest levels occurring in June-July and lowest levels during the winter months. This seasonal water level pattern is opposite that in shallow, freshwater swamps which may dry up during the middle of the growing season. Cattails appear to be favored by low water levels in winter because oxygen diffuses through exposed stalks down into the roots and rhizomes (Jaworski et al. 1979).

However, it is the longer term lake level oscillations which have the greatest effect on vegetation succession. In the Great Lakes the hydroperiod for these longer term oscillations is 8 to 20 years (U.S. Dept. of Commerce 1976). Near record low water levels - at about 174 m above datum (IGLD) - occurred in 1964-1965, whereas record highwater levels - at approximately 176 m above datum (IGLD) - took place during the 1972 to 1974 interim. Because of these cyclic water level oscillations, succession is always taking place in the plant communities.

The lateral shifts of the plant communities in response to water level fluctuations are illustrated by Figures 32 and 33 of Section 3.2. Dickinson Island was utilized for this discussion because it has an intact environmental gradient over which vegetation shifts can occur. Elsewhere on Harsens Island as well as on the Canadian side of the St. Clair Delta, the cattail marsh ends abruptly against dikes or canals, and much of the sedge and other drier habitat communities have been developed.

These successional changes can be documented by a series of transects taken over time across the same survey line. As indicated by Figure 48, water level changes in the coastal wetlands of Lake St. Clair caused dramatic vegetation changes. Beginning in July 1964, one can observe extensive communities of cattail, sedge, and dogwood meadow. However, during the high water period of the 1970s, widespread dieback occurred as far inland as the shrub/swamp fringe which borders on the oak-ash hardwoods. During such conditions, much of the cattail marsh consisted of open water as well as communities of bulrushes and submersed aquatics. Notice that by the summer of 1977, considerable reestablishment began to take place as water levels dropped somewhat.

A plant community displacement model can be used to predict community succession associated with water level fluctuations. As illustrated in Figure 49, each wetland plant community has been placed at its proper elevation in relation to the long-term mean water level. The length of the line under the plant community's name indicates the amount of vertical shifting which that community exhibits. To use this model, note that the communities shift lakeward (to the left) during low water levels and displace communities along their lakeward margin. To simulate succession during rising lake levels, shift the communities to the right along their respective displacement lines. As one moves upward along the environmental gradient, the extent of community displacement is less and core areas persist during both low and high-water periods. Therefore, the shrub/swamp fringe zone shifts least and is displaced less by the adjacent plant community.

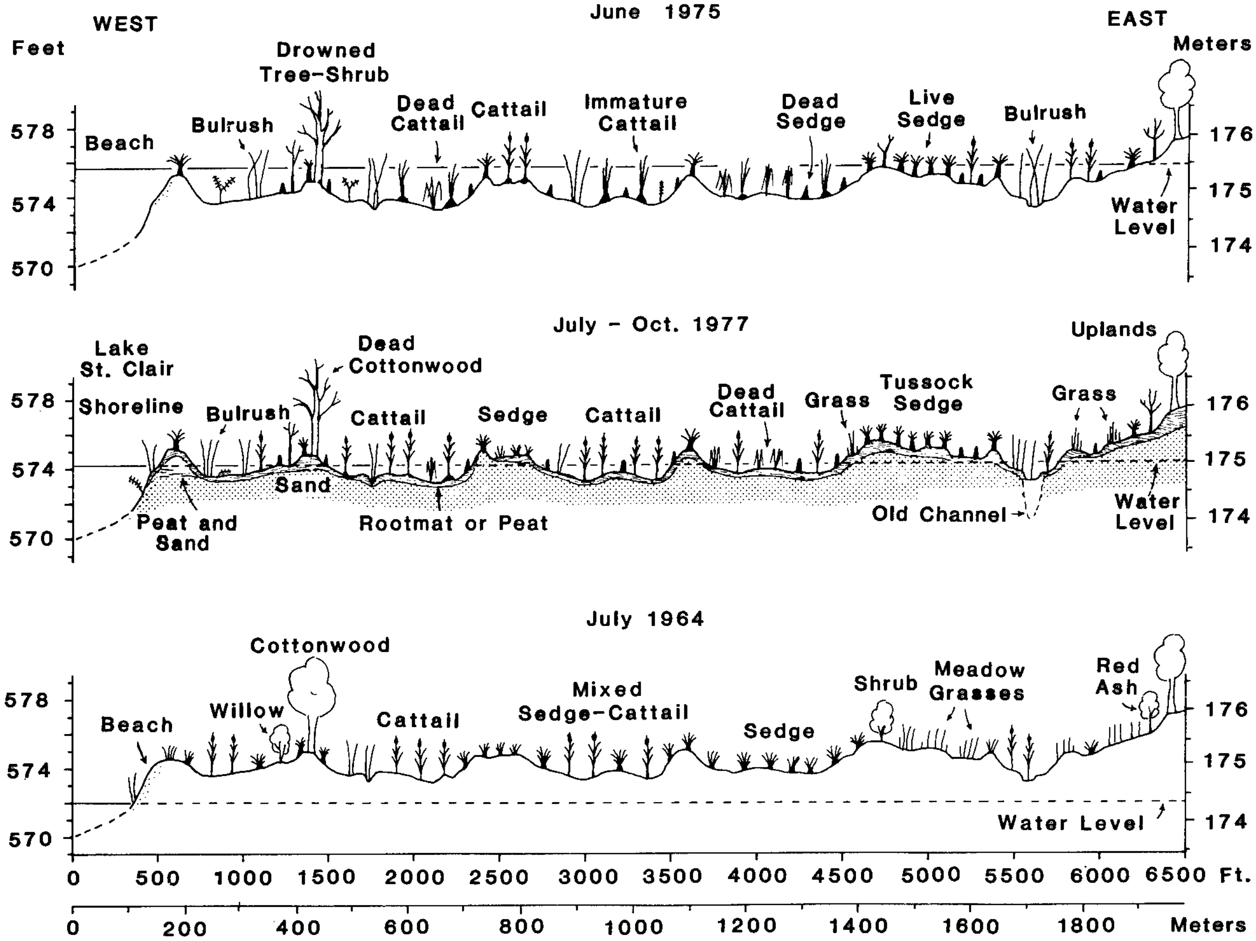

Figure 48. Successional changes on Dickinson Island in response to water level fluctuations.

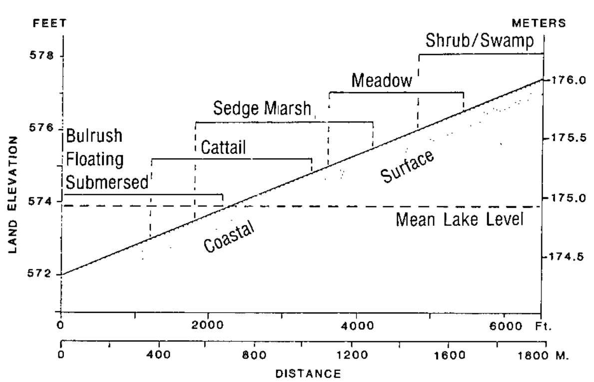

Figure 49. Wetland plant community displacement model for Dickinson Island showing predicted response to water level changes.

As shown in Table 32, the wetland plant communities not only change location but alter their areal extent in response to these long-term water level oscillations. The dominance of the emergent cattail and sedge marsh during low-water levels is clear. In contrast, during high water periods, the wetlands exhibit extensive floating leaved and submersed communities along with the cattails. The cattail marsh actually appears more widespread during high water conditions than it is because the dead cattail stalks often remain in place for several years. Notice, too, that the area of the shrub/swamp changes very little as the water levels change. This situation prevails because the shrub/swamp community

Table 32. Vegetation changes on Dickinson Island in response to lake level fluctuations.[a]

Vegetation class	Percent of total area[b] Low water 1964	Mean level	High water 1975
Open water	0.5	4.0	7.5
Floating leaved/ Submersed	5.0	17.5	30.0
Emergents (cattails)	37.0	31.5	28.0
Sedge marsh	36.5	23.0	13.0
Dogwood meadow	9.0	6.5	4.0
Shrub/Swamp	10.0	10.0	10.0
Developed areas	2.0	7.5	7.5
	100.0%	100.0%	100.0%

[a]Data source: Jaworski et al. (1979).

[b]Note: Total area 1,130 hectares (2,800 acres).

is slightly higher in elevation than the high water mark and it is difficult to separate dieback shrub from live brushy vegetation. Also, cattail is an aggressive invader compared to sedges and dogwood.

The zonation exhibited by the wetland plant communities has previously been illustrated by Figures 26 and 33 and described in Section 3.2. These plant zones, in order from upland to aquatic sites, are: shrub/swamp, dogwood meadow, sedge marsh, cattail marsh, and open water floating/submersed communities. In many wetlands along Lake St. Clair urban development and other land uses have progressed from the adjacent upland areas lakeward to the emergent marsh. Only on Dickinson Island, and to some extent in Bouvier Bay (i.e., St. John's Marsh), does a complete environmental gradient, or full zonation of wetlands, exist today.

Animal Zonation

Species diversity of invertebrates tends to be higher in St. Clair Delta wetland ecosystems than in nearshore benthic and profundal benthic zones of Lake St. Clair. Invertebrate productivity also tends to be higher in wetlands compared to open water areas and it appears that invertebrate productivity tends to be higher in emergent wetlands compared to submergent wetlands (Tilton et al. 1978). Invertebrate populations in coastal wetlands are a food source for higher trophic levels in the food web, comprising a major fraction of the diet of numerous species of fish, reptiles, amphibians, birds, and mammals.

Several species of forage fish (spottail, blacknose, and emerald shiners) feed or spawn in wetland ecoysystems. These forage fish are consumed by piscivorous fish as well as birds and mammals. Loss of wetlands which produce forage fish can cause a reduction in the numbers of piscivorous fish as well as birds such as the kingfisher and common mergansers (Tilton et al. 1978).

Zonation has also been demonstrated for larval fish populations in western Lake Erie (Cooper et al. 1981a, 1981b, 1984; Mizera et al. 1981). A series of studies in the estuaries and open waters of western Lake Erie has shown that the estuaries of the Maumee and Sandusky Rivers contained the highest densities of

larval fish when compared with other nearshore and offshore areas. Gizzard shad, white bass, and freshwater drum dominated the estuarine populations. The highest density of yellow perch was found in nearshore areas associated with sandy bottoms, particularly north of Woodtick Peninsula and in the vicinity of Locust Point. The following depth/density relationship was observed for this species:

Water depth (m)	Maximum number/100m^3
0 - 2	157.0
2 - 4	19.3
4 - 6	7.7
6 - 8	5.2
8 - 10	5.0
> 10	3.7

The same general relationship was found for most species, indicating a greater preference for spawning and nursery grounds in the coastal areas. A similar pattern is suspected for Lake St. Clair. Surveys conducted by Hatcher and Nester (1983), although not in the lake proper, show high densities in the St. Clair Delta and at the head of the Detroit River.

Johnson (1984) believed that the most important factor influencing production of fish larvae in western Lake Erie marshes is predation. Although no information is available on predator-prey interactions involving larval fish in Lake St. Clair wetlands, related research has indicated habitat structure can be important in mediating the outcome of aquatic predator-prey interactions. Glass (1971) found that largemouth bass (Micropterus salmoides) predation success declined as the complexity of habitat structure increased. Crowder and Cooper (1979) concluded that areas of high structural complexity should create an effective refuge for prey and enhance their survival. However, Helfman (1979) found prey-sized bluegill (Lepomis macrochirus) were strongly attracted to shade produced by 1 m diameter floats in which no submerged structure was present. He concluded prey fish in shade can detect a predator (in sun) long before the predator can detect the prey.

Therefore, prey species and prey-sized fish may actively escape predators by disappearing into areas of high structural complexity or by seeking shade so as to gain the visual advantage. Consequently, fish larvae in wetlands may use floating habitat types to gain the visual advantage while other larvae may use submergent or emergent habitat types to hide from potential predators. Open water areas in Lake St. Clair coastal marshes may be expected to have low larval use during the day because of the increased success of visual predators in this habitat type, but these areas, particularly the uncontrolled wetlands, may be important to fish larvae at night.

Waterfowl Migration

The coastal marshes of Lake St. Clair attract large numbers of migratory waterfowl. Located at a crossing point on two major flyways, these marshes attract ducks from eastern Canada heading for wintering grounds on the Mississippi River bottoms and ducks from the prairie provinces of Canada which winter along the Atlantic coast. Beds of wild celery are particularly attractive to great numbers of canvasbacks (Aythya valisineria), redheads (Aythya americana), and scaups (Aytha spp.) migrating southeastward to their wintering grounds on Chesapeake Bay (Andrews 1952).

Lincoln (1935) introduced the concept that all populations of migratory birds adhere to their respective flyways as they make their semiannual flights between breeding grounds and wintering grounds. Four distinctive flyways have been identified for North America, two of which cross western Lake Erie and Lake St. Clair: the Atlantic Flyway and the Mississippi Flyway. These routes are used by all of the migratory waterfowl and other waterbirds which frequent the coastal wetlands. Each flyway has its own individual population of birds, even for those species which have a broad continental distribution. The breeding grounds of two or more flyways may, and often do, overlap broadly so that during the nesting season extensive areas may be occupied by birds of the same species, but which belong to different flyways.

In the fall, the Atlantic Flyway receives accretion of waterfowl from several interior migration paths starting

at the breeding grounds on the Arctic tundra. Canada goose (Branta canadensis), and diving ducks, including canvasbacks, redheads and scaup come from their breeding grounds on the great northern plains of central Canada, follow the general southeasterly trend of the Great Lakes, rest in the St. Clair Delta, cross Lake Erie in the islands region, and continue over the mountains of Pennsylvania to winter along the Atlantic coast in Chesapeake and Delaware bays. Concurrently, dabbling ducks such as mallards (Anas platyrhynchos), black ducks (Anas rubripes), and blue-winged teals (Anas discors) that have gathered in staging areas of southern Ontario (including the St. Clair Delta) also leave these feeding grounds, cross western Lake Erie and proceed southwest over a course that leads down the Ohio and Mississippi valleys (Mississippi Flyway). However, part of this duck population, upon reaching the St. Clair Flats, swings abruptly to the southeast, crosses the Appalachian mountains and winters along the Atlantic coast (Lincoln 1950).

The Mississippi Flyway is easily the longest migration route of any in the Western Hemisphere. Its northern terminus is the Arctic coast of Alaska, while its southern end lies in the Patagonia region of Argentina. Although the main path of the flyway lies to the west of the Great Lakes, major branches follow the southern trend of Lake Michigan and the southwestern trend of Lake Erie and the Maumee River valley. Some of the black ducks, mallards, and teals that cross the Great Lakes in the vicinity of Lake St. Clair do not turn abruptly to the southeast, but continue on to the southwest as members of the Mississippi Flyway bound for the Gulf of Mexico coast rather than the Atlantic seaboard. Fall migration is at its peak in September and October, but the main shorebird passage is underway in August.

Spring migration begins in late February with the appearance of ring-billed gulls (Larus delawarensis) in Lake St. Clair. March and early April bring heavy waterfowl movement, ducks and loons (Gavia sp.) appearing in open leads as soon as the ice breaks up. Red-winged blackbirds (Agelaius phoeniceus) move in large numbers starting in late March. The huge Canada goose movement normally takes place in early April. With April and May comes the major push of spring migration, especially the landbirds. Migrants are less selective than breeding birds in their choice of habitat, nevertheless, waterbirds prefer shorelines with pockets of vegetation. Coastal marshes and stream mouths commonly attract migrating dabbling ducks. The open water shorelines concentrate the diving duck migrants and other waterbirds including loons, grebes, cormorants (Phalacrocorax auritus), tundra swans (Cygnus columbianus), redheads, canvasbacks, lesser scaups (Aythya affinis), and red-breasted mergansers (Mergus serrator).

For over three decades after Lincoln defined and mapped his four waterfowl flyways of North America, little new work was published on the subject. Then, Bellrose (1968) published his outstanding treatise on waterfowl migration corridors east of the Rocky Mountains. In addition to these data and ground observations, Bellrose used such advanced techniques as visual sightings from aircraft and radar surveillance. One impetus for undertaking this revision was the increasing hazard to aircraft from migrating birds.

Bellrose found that Lincoln's flyway concept, although still valid on a grand scale, tended to oversimplify the migration process. He observed that flyways were in reality a complex of corridors (Figures 50-52). Each corridor, in turn, is a web of routes as opposed to a single, narrow band rigidly followed by the waterfowl. The migration corridors represent passageways, each connecting a series of waterfowl habitats. Migration corridors differ from flyways in being smaller and more precisely defined as to species. Bellrose considers the flyways proposed by Lincoln to be primarily geographical and secondarily biological, while his corridors are primarily biological and secondarily geographical.

As waterfowl migrate between breeding grounds and wintering areas, they stop to rest and feed in wetlands. These wetlands are referred to as "concentration areas." The coastal wetlands of Lake St. Clair, the lower Detroit River, and western Lake

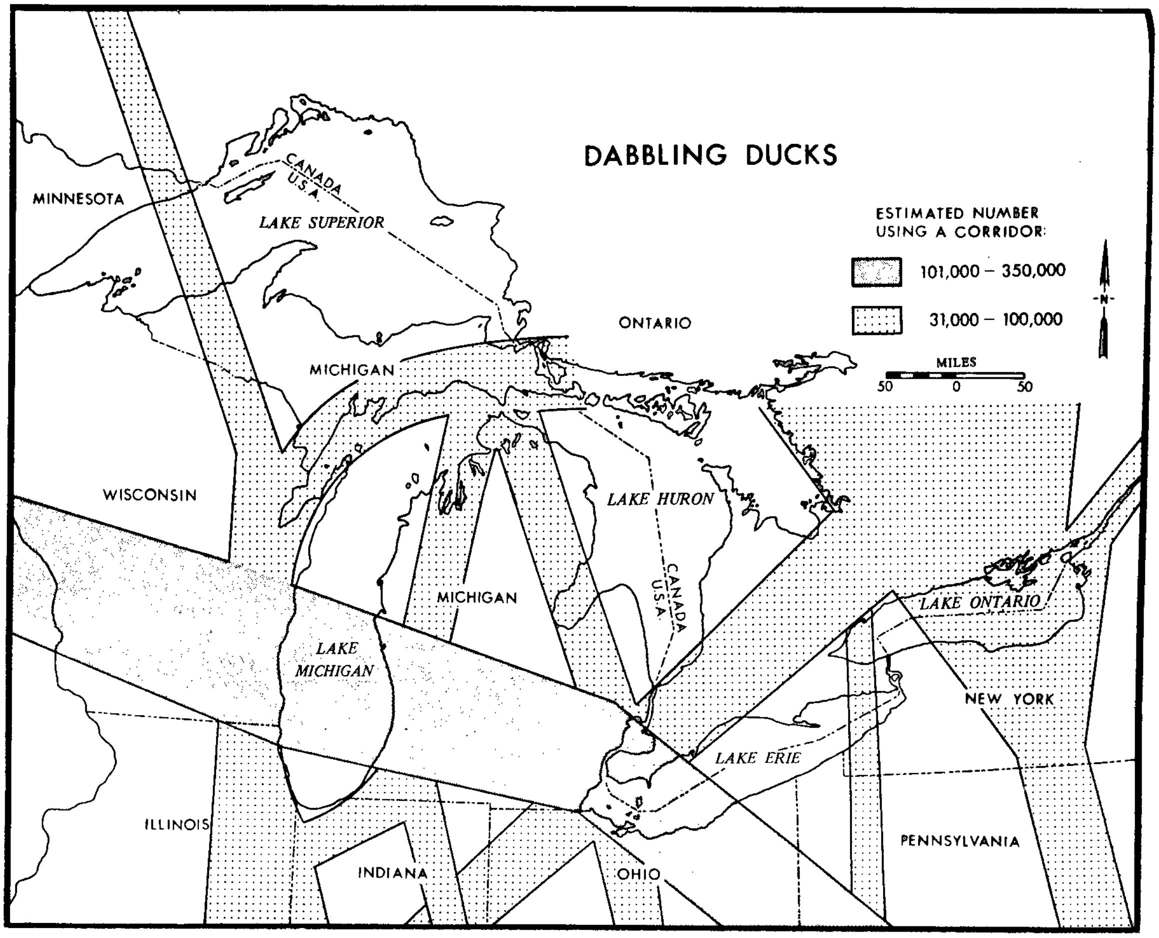

Figure 50. Fall migration corridors for dabbling ducks (Tribe Anatini) across Lake St. Clair (Bellrose 1968).

Erie provide some of the finest concentration areas of this type along the flyways. These areas are characterized by an abundance of waterfowl foods, as well as by low wave energy and low human disturbance. Canvasbacks, redheads, American wigeons (Anas americana), ring-necked ducks (Aythya collaris), and coots (Fulica americana) feed extensively on submersed plants, whereas shovelers (Anas clypeata), oldsquaws (Clangula hyemalis), common goldeneyes (Bucephala clangula), and mergansers appear to prefer crayfish, small fish, and other animal foods. Black ducks, mallards, pintails (Anas acuta), teals, scaups, and buffleheads (Bucephala albeola), select from both plant and animal foods. Canada geese and mallards also feed heavily on waste grains in agricultural fields. Food availability may be more important than food preference, especially during the spring migration when food supplies are less abundant. Food availability in wetlands is reduced by extreme high and low water levels, heavy siltation, turbidity, heavy hunting pressure, and other disturbances.

Jones (1982) examined the food preference of wintering goldeneye, greater scaup, and lesser scaup at the mouth of the Detroit River. He determined that 30 food taxa were utilized by the waterfowl including 10 plant and 20 animal preferences. Wild celery (Vallisneria americana), pondweeds (Potamogeton spp.) and other plant species made up over 60% of the food budget of most of the sampled

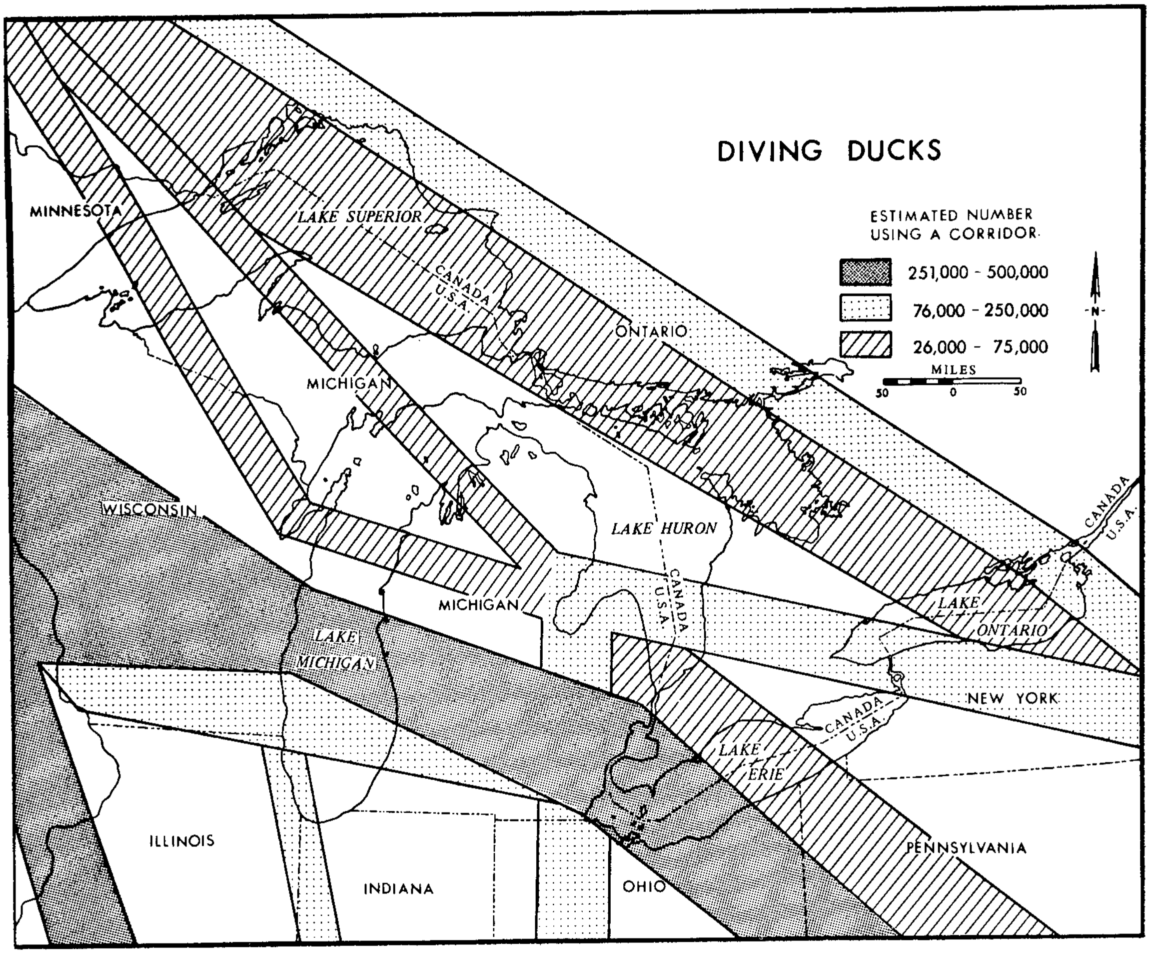

Figure 51. Fall migration corridors for diving ducks (Tribe Aythyini) across Lake St. Clair (Bellrose 1968).

waterfowl. Miller (1943) and Bellrose (1976) have found that other diving ducks, particularly canvasbacks and redheads, feed on submersed aquatics such as those noted above as well as waterweed (Elodea canadensis).

In western Lake Erie marshes, Bednarik (1975) found that preferred natural foods of diving ducks, such as wild celery, appeared to be more adversely affected by turbidity and siltation than foods of dabbling ducks and geese. In general, Great Lakes conservation agencies do not encourage the creation of resident wintering flocks, particularly in the Lake St. Clair region, because of the problem of waterfowl starvation during severe winters. Waterfowl that reach the spring breeding grounds in good condition tend to exhibit greater nesting success than those which are undernourished (Bellrose 1976).

Dabbling ducks. These ducks are so called because they normally do not dive below the water for food, but merely dabble on the bottom in shallow water. Annually about 17,500,000 mallards and pintails migrate down flight corridors from Canada to the United States east of the Rocky Mountains (Bellrose 1968). The largest portion, about 12,275,000, enter the geographical confines of the Mississippi Flyway from the northern Great Plains. About 20% of these birds continue across the Mississippi Flyway and move down the Atlantic Flyway. In addition, another 650,000 black ducks move south from Ontario and Quebec.

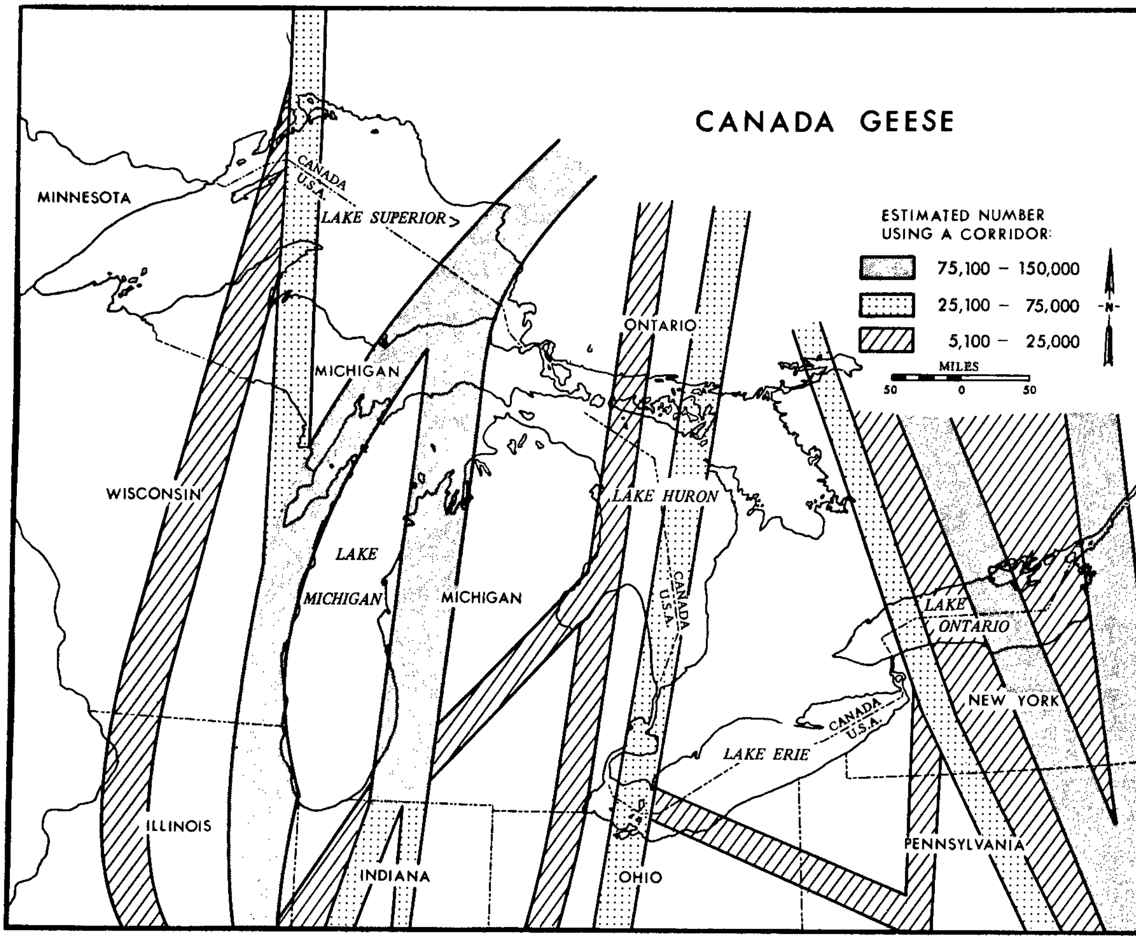

Figure 52. Fall migration corridors for Canada geese (Branta canadensis) across Lake St. Clair (Bellrose 1968).

Several corridors carrying dabbling ducks cross the Great Lakes region (Figure 50). An estimated 65,000 mallards, 35,000 wigeons, and 25,000 pintails move eastward along the Chesapeake Bay Corridor. The corridor starts in the upper Mississippi River valley and progresses eastward through Wisconsin, Michigan, and Ohio. It encompasses the marshes of Lake St. Clair and Lake Erie from Algonac, Michigan, to Sandusky Bay. From these marshes it is a 645 km, non-stop flight to Chesapeake Bay where most of these ducks winter. The Black Duck Corridor extends southwestward from eastern Ontario, across Lake St. Clair to the confluence of the Wabash and Ohio rivers, and on south to Arkansas. Approximately 35,000 black ducks use this path.

Diving ducks. As the name suggests, these ducks normally dive below the water for food. About 4,200,000 diving ducks annually migrate south into the United States east of the Rockies (Bellrose 1968). Slightly over 60% of these are scaups. Redheads are second in abundance at 20%, while canvasbacks and ring-necked ducks each form about 7% of the population. As with the dabbling ducks, numerous diving duck migration corridors cross the Great Lakes region (Figure 51).

The Southern Michigan Corridor takes the main flow of diving duck passage from eastern Wisconsin, across southern Michigan to Saginaw Bay and the Lake St. Clair-Detroit River-Lake Erie wetlands areas. Diving ducks congregate on Saginaw

Bay to the extent that peak numbers include 22,000 lesser scaups, 22,000 redheads, and 7,000 canvasbacks. Approximately 160 km to the south, peak populations of 380,000 lesser scaups, 260,000 canvasbacks, and 42,000 redheads have been observed from Lake St. Clair to western Lake Erie. Although as many as 15,000 diving ducks may winter on the Detroit River, at least 700,000 fly on from Lake St. Clair to wintering grounds in the Atlantic Flyway. This route is known as the Chesapeake Bay Corridor and is a similar route to the one taken by mallards and pintails.

Geese. More than any other species of waterfowl, Canada geese have radically altered their migration routes in the past few decades. Bellrose (1968) attributed this great change in their migration habits to their rapid adoption of newly created waterfowl refuges. They are still in the process of evolving new migration corridors. Currently, about 1,300,000 Canada geese leave Canada in the fall for wintering grounds in the United States. The largest number, 600,000 use the Atlantic Flyway, while another 475,000 take the Mississippi Flyway. Most of the Atlantic Flyway crossings of the Great Lakes take place over Lake Ontario, but one corridor uses the marshes of Lake St. Clair (Figure 52). The main migration corridor for Canada geese in the Mississippi Flyway extends down the west shore of Lake Michigan, then down the Mississippi River valley.

Snow geese (Chen caerulescens) use the Mississippi Flyway. Each October about 450,000 birds leave Canada for wintering grounds on the coastal marshes of Louisiana. The main corridors follow the east and west shores of Lake Michigan, converging in the Mississippi River valley north of Louisiana. The easternmost flight corridor, used by about 15,000 geese, runs from the south end of James Bay to the marshes of Lake St. Clair and western Lake Erie, then turns southwestward across Indiana. A somewhat larger number of birds uses a corridor that extends from James Bay through Saginaw Bay, and then merges with the flight path from Lake St. Clair.

4.4 WETLANDS AS HABITAT TO FISH AND WILDLIFE

Because the Lake St. Clair wetlands are composed of a variety of habitats including open ponds, cattail/reed marshes, earthen dikes, barrier beaches, delta flats, and wooded swamps, many species of plants and animals are attracted to the coastal marsh community. Of particular importance to fish and wildlife, both resident and transient species, are the following considerations: 1) food chain production and energy flow, 2) fish production, spawning, and nursery, 3) waterfowl migration, wintering and nesting, 4) mammal forage, and 5) invertebrate habitat. Dole (1975) estimated the density of wildlife in the vicinity of Lake St. Clair (Table 33). Most animals showed a stable trend, but a few important species are decreasing in abundance.

Although there are scattered patches of wetlands around the perimeter of Lake St. Clair, the wetlands in the St. Clair Delta provide the most valuable habitat for fish and wildlife, including waterfowl. Not only are these deltaic wetlands productive, they are diverse and exhibit high connectivity to the St. Clair River channels as well as to Lake St. Clair.

With regard to fish spawning in these wetlands, important species include the following: lake sturgeon, northern pike, muskellunge, carp, golden shiner, emerald shiner, common shiner, spottail shiner, spotfin shiner, channel catfish, bullheads, rock bass, pumpkinseed, bluegill, sunfish, and walleye (Figure 39). It has been suggested that ice fishing, as in Little Muscamoot Bay of Harsens Island, is particularly good because wetlands are an important source of fish foods in winter (W. C. Bryant, MDNR, Fisheries Division, pers. comm.). However, except for gizzard shad, most fish migrate to deeper waters in fall and return to the shallow, nearshore environments following ice breakup (Werner and Manny 1979). Because wetlands warm up more quickly than Lake St. Clair in the spring, these coastal environments may be a critical source of food for fish attracted to the shorelines.

Table 33. Status of wildlife in the vicinity of Lake St. Clair and connecting waterways (1970).[a]

Wildlife group and species	Density	Trend
Big game		
White-tailed deer	low	increasing
Waterfowl		
Ducks	high	stable
Geese	medium	increasing
Small game		
Cottontail rabbit	medium	stable
Ring-necked pheasant	high	stable
Ruffed grouse	low	stable
Gray squirrel	low	decreasing
Fox squirrel	medium	stable
Woodcock	low	stable
Mourning dove	high	stable
Bobwhite quail	low	stable
Furbearers		
Muskrat	high	stable
Mink	medium	stable
Beaver	low	decreasing
Weasel	medium	stable
Raccoon	medium	increasing
Skunk	high	increasing
Opossum	high	stable
Badger	low	stable
Non-game		
Woodchuck	medium	stable
Red fox	medium	stable
Gray fox	medium	stable
Crow	high	stable
Red squirrel	low	stable
Coyote	low	stable
Raptors	medium	stable
Rare and endangered		
Bald eagle	low	decreasing
American osprey	low	decreasing
Unusual or unique		
Sandhill cranes	medium	stable
Golden eagle	rare	transient

[a]Data source: Dole (1975).

With regard to wildlife habitat, the St. Clair Delta wetlands are also exceptional. The main reasons for this outstanding habitat quality are: 1) large areas of relatively pristine wetlands, 2) habitat diversity (several wetlands exhibit complete environmental continuums), and 3) relatively few barriers to movements. Dickinson Island and the Bassett Island-Goose Lake areas represent relatively pristine wetlands with direct hydrologic connection to Lake St. Clair and few barriers to movements or migration. In Figure 31, one can readily see the habitat diversity, juxtaposition of environments, and mix of open water and vegetation which contributes to high wildlife values (Weller and Spatcher 1965).

The importance of the coastal wetlands along Lake St. Clair with reference to waterfowl has already been discussed in Section 3.6. Although some waterfowl breeding does occur in the delta wetlands, the primary importance of the St. Clair River wetlands is in regard to resting and feeding habitat during migration. Because of availability of preferred plant and invertebrate foods (Dawson 1975), as well as its location along the Atlantic and Mississippi Flyways (Bellrose 1968, 1976), these wetlands serve as concentration areas and stopover points for both diving and dabbling ducks. Habitat degradation along western Lake Erie and Saginaw Bay, due to excessive turbidity, siltation and water quality decline (Martz and Ostyn 1977; U.S. Department of Interior 1977), is associated with greater reliance on the St. Clair Delta wetlands. In this regard, the waterfowl habitat deficiencies predicted for southeast Michigan as of the year 2000 are most significant (U.S. Department of Interior 1971).

Large numbers of furbearers as well as birds, reptiles, and amphibians have been identified in the St. Clair Delta wetlands (Herdendorf et al. 1981c). Muskrats abound in the cattail marshes and raccoons are particularly numerous where large trees occur. In comparison to the Canadian wetlands, which consist largely of cattail marshes and open-water areas, the Dickinson Island wetlands on the American side of the delta exhibit much greater habitat diversity. Given access by boat via the abandoned channel which winds across Dickinson Island, both consumptive and nonconsumptive users can easily enjoy this rich wildlife resource.

To evaluate fish, wildlife and other values of wetlands, the Michigan Department of Natural Resources has developed a field evaluation manual (Wolverton 1981). However, the St. Clair Delta wetlands have not been rated by this agency. Nevertheless, because of its exceptional fish, waterfowl, and other wildlife values, along with its accessibility to users and relatively undeveloped nature, particularly Dickinson Island, these wetlands may well be among the most valuable in the Great Lakes region.

CHAPTER 5. HUMAN IMPACTS AND APPLIED ECOLOGY

5.1 WETLAND DISTURBANCE

A new awareness has arisen in the last decade over the alarming loss of wetlands. In Michigan, 71% of the coastal wetlands have been lost (Jaworski and Raphael 1978), and much of the remaining 42,420 ha have been altered because of degraded water quality, changes in hydrology, and other factors. However, losses and degradation are not solely due to human intervention. Western Lake Erie has suffered a significant loss of aquatic vegetation, possibly because of changing lake levels, water movements, and carp feeding habits (Core 1948; Stuckey 1971). Seiches and flooding may temporarily reduce emergent wetlands; however, regeneration usually occurs. Conversely, human impacts such as dredging, filling, diking, and draining have a permanent adverse impact on the resource base.

Historical Perspective

Adverse impacts in the St. Clair wetlands began with the exploitation of fish and wildlife prior to European contact and continued into the 1850s. However, these impacts were modest and the losses somewhat replaceable through natural reproduction. Impacts which followed were more permanent. We will discuss the adverse impacts within a historical framework spanning about 125 years (Figure 53). This is how our present problems emerged and this is the way they have been addressed.

Historically, modification of the wetlands of Lake St. Clair began shortly after European contact. Historical accounts suggest that the wetlands of Lake St. Clair were not excessively exploited by the fur traders as were other wetlands of the Great Lakes such as those along western Lake Erie. An abundance of wildlife and fish attracted farmers from the settlement at Detroit. The desirable quality and quantity of fish and wildlife led to the establishment of fishing and hunting clubs. In the mid-19th century, one such club, the Lake St. Clair Fishing and Shooting Club, spent $80,000 to improve the property it occupied in the delta (Jenks 1912).

Historic maps reveal that the wetlands were not impacted significantly in the 1850s (Meade 1857). Although maritime commerce was carried on through the lake and its distributary channels, emergent aquatics were abundant and diverse throughout the St. Clair Delta and the mouth of the Clinton River. Jenks (1912) noted that wild rice (Zizania aquatica) was abundant as were at least 116 species and 25 varieties of wetland macrophytes, including sedges. Fish and wildlife were exploited in a non-commercial capacity in the area. In 1857 New Baltimore was the only community in the northern part of Lake St. Clair.

Significant wetland disturbances are associated with two interrelated cultural processes: agricultural development, which was followed by urban growth. The surveyor-general of the United States reported in 1815 that a large part of the southeastern region of the Michigan territory was swamp and practically worthless. As early as 1826 attempts were made for reclamation; but it was not until September 1850 that a general swampland law was enacted. Its purpose was to allow for draining and diking of "worthless public lands, lying as marshes or subject to periodic overflow by adjacent watercourses" (Donaldson 1970).

The 1850 swamp act stimulated significant wetland alteration. By 1873

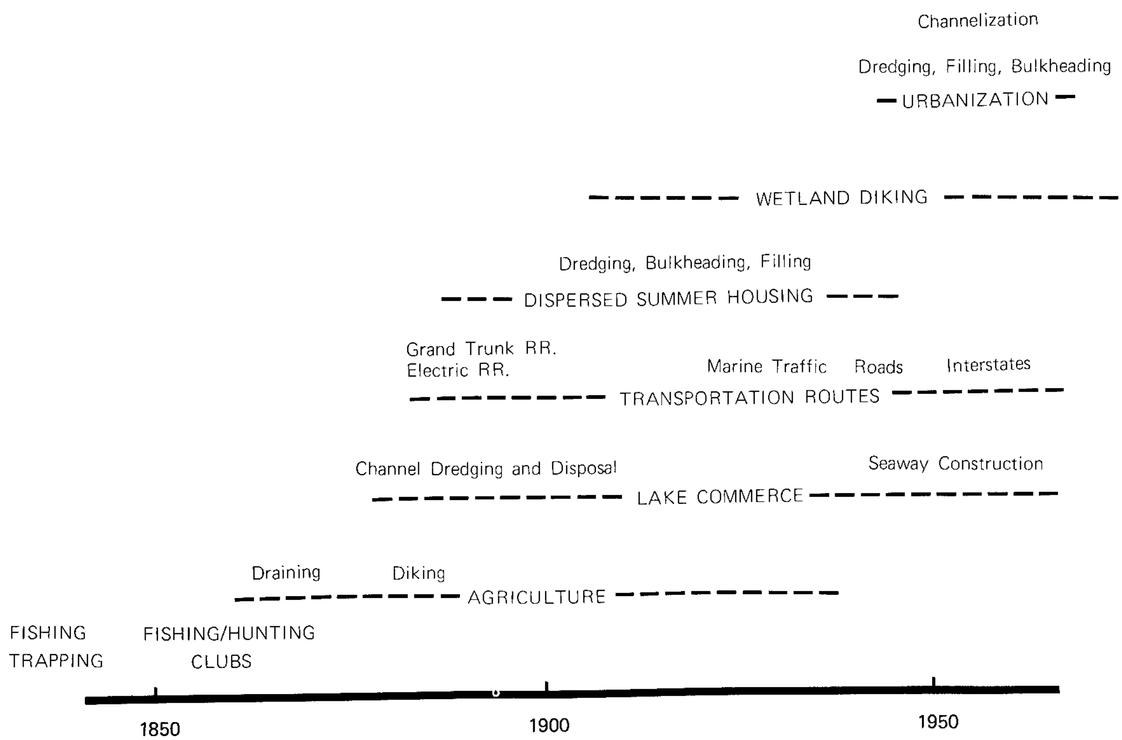

Figure 53. Historic trends in Lake St. Clair wetland disturbance.

the land cover between the Detroit and Clinton Rivers was in agriculture. The north shore of the lake also supported agriculture. Established villages such as New Baltimore grew, and new urban centers such as Anchorville were founded. Wetlands at the head of the Detroit River were also being dredged. On the St. Clair Delta, hardwood forests of the premodern delta were cleared for farmland. About half of the modern delta on Harsens Island was diked.

Three methods of transportation which were firmly established by the mid-1870s provided improved access to the shoreline and delta. An electric railway was constructed along the perimeter of the lake from Detroit to beyond Algonac. The railbed was built on the higher ground, generally avoiding the remaining wetlands. Nevertheless, between New Baltimore and Algonac, the railroad bed was constructed through St. John's Marsh, a shallow inter-distributary bay colonized with emergent aquatics.

A second mode of transport with adverse impacts on the delta was the establishment of the St. Clair Ship Canal, a 6 m channel dredged through South Channel for commercial navigation.

When the Grand Trunk Railway, the third mode, was constructed, it dissected the remaining wetlands in several places. However, on this shoreline most of the wetlands had already been drained so the effect of this railroad was not particularly adverse.

Several sportsmen's clubs were established between 1850 and 1873 in Ontario on portions of the delta which are accessible by boat. For example, in Ontario the Ste. Anne Club and the Canada Club were founded, while in Michigan the Grande Pointe and the Old Clubs were established. Hotels to accommodate summer tourists from Detroit were constructed on the South Channel levee. Since the levees were low and subject to periodic flooding, bulk-heading began to appear. Isolated filling and bulkheading was most intense along South Channel (the main navigation channel) and in a few isolated localities. The first road on the St. Clair Delta was

constructed on the west side of South Channel to allow access and settlement. In contrast, the shoreline from the Thames River northward remained unaltered except for limited settlement in the northern portion of Walpole Island.

Channelization for commercial navigation began in earnest in 1886. The U.S. Congress authorized the deepening of the Clinton River (Figure 54) to 2.4 m, and Lake St. Clair and the St. Clair Flats Channel to a depth of 8.4 m. By 1892 the St. Clair River was dredged as well. On the lower portion of South Channel, channels were dredged through the natural levees into Big Muscamoot Bay and bulkheading and backfilling for summer housing continued. By 1903 the modern delta wetlands (the shallow interdistributary bay) of Harsens Island continued to be drained, diked, and used for agriculture.

The period 1900-1930 was the beginning of urbanization. Channels and roads were constructed along Middle and South Channels. The electric railroad was removed and replaced by highway M-29, linking Algonac with communities to the west. Recreational boating facilities began to appear. Urban areas and waterways expanded at the expense of agriculture. Urbanization more than doubled and agricultural land use declined to one-half in the St. John's Marsh area (Table 34 and Figures 55 and 56). Direct impacts on the wetlands continued.

In 1945 intense commercial and urban growth began. Urban strip development extended from Detroit to Algonac. Dredging, filling, and channelization consumed and drained a significant portion of St. John's Marsh. Urban development also extended along the perimeter of Harsens Island. To improve waterfowl habitat, most of the remaining portion of Harsens Island was diked and planted in corn and other crops. Although most of the Ontario portion of the St. Clair Flats still remains as the Walpole Island Indian Reserve, south of Mitchell Bay wetlands have been drained and channelized for agriculture. Dikes were constructed to alleviate flooding and control water levels in formerly unrestricted wetlands. The diking projects on Harsens Island and in Ontario extended into the cattail marsh. Sedge and dogwood/meadow wetlands which are located at or just above the water table, were the areas initially drained for agriculture. An analysis of coastal land use, based on 1973 topographic maps during record high lake levels reveals that the only significant areas of intact wetlands in Michigan were within the interdistributary basins of the St. Clair Flats and a small area south of the Clinton River. In 1985 the Michigan wetlands of Lake St. Clair represented only some 2,000 hectares of the land cover.

Commercial and recreational traffic has also had a considerable impact on Lake St. Clair. Bulk cargo and recreational boating have required channel deepening. New channel and marine construction on the Lake St. Clair shoreline continues. Public maintenance dredging to accommodate lake carriers and private recreational craft is estimated to be 122,000 m^3 annually (Raphael et al. 1974) exclusive of the St. Clair River. The construction of highway I-94 from Detroit northward to Port Huron has improved access to the Lake St. Clair shoreline. Reduced driving time from Anchor Bay and Algonac to Detroit has encouraged suburban development, particularly along the western shoreline of Lake St. Clair. All of these factors have stimulated development of the shoreline and have had adverse impacts on many of the wetlands.

In part, because of the exceptional fish and wildlife productivity and

Table 34. Land use change at St. John's Marsh.[a]

Land use	1938		1974	
	ha	acres	ha	acres
Urban	126	313	320	793
Agriculture	822	2,035	431	1,066
Waterways	21	52	109	269

[a]Data source: Roller (1977).

Figure 54. Aerial photograph of the mouth of the Clinton River, Macomb County, Michigan, showing a coastal wetland (Verchev's Marsh) isolated from Lake St. Clair by channelization and residential development (June 1975).

Figure 55. Aerial photograph of St. John's Marsh on Bouvier Bay, and North Channel, St. Clair Delta (April 1949). Note wetlands established during low lake levels. Compare with Figure 56.

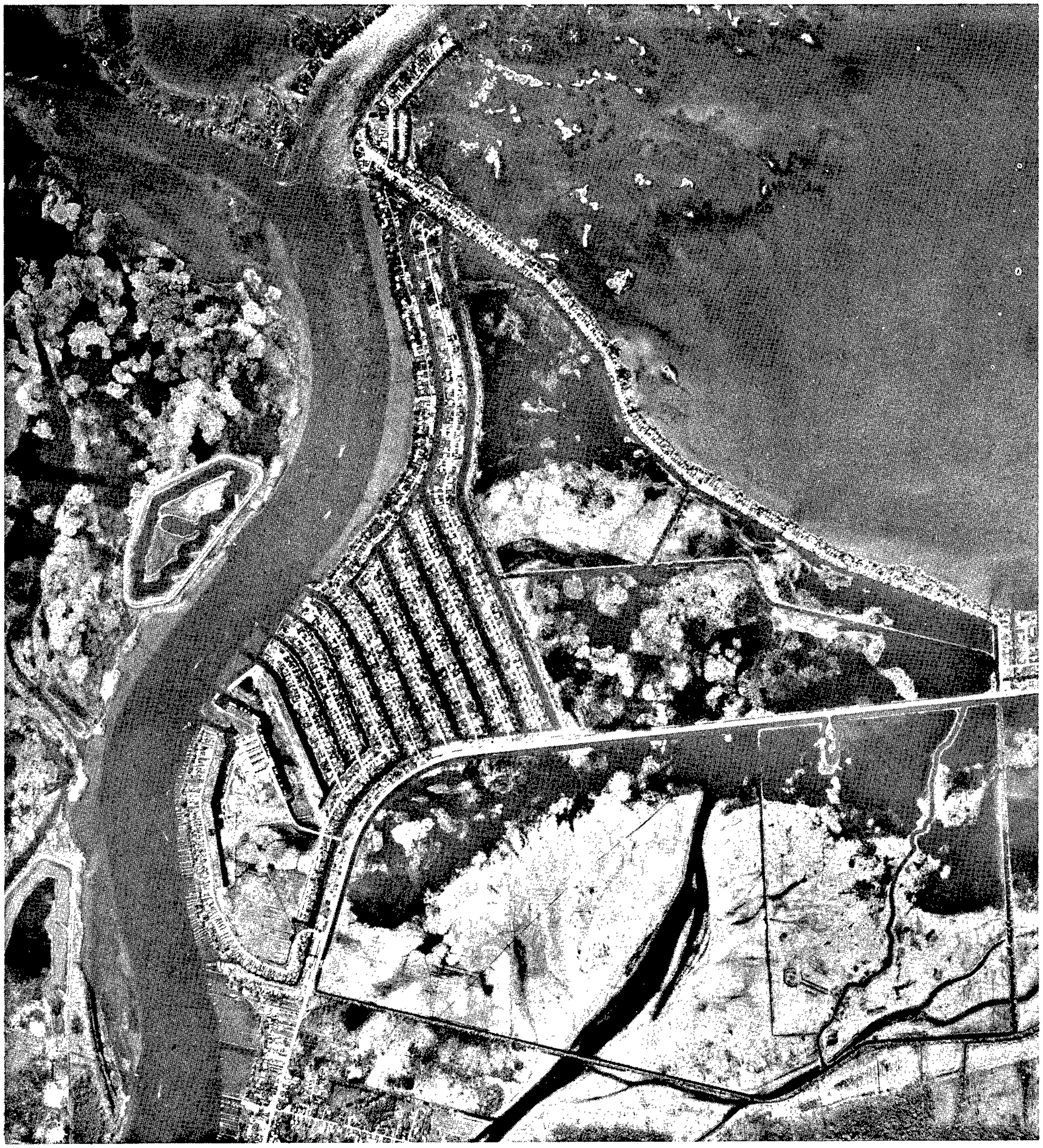

Figure 56. Aerial photograph of North Channel, St. Clair Delta, and St. John's Marsh on Bouvier Bay (May 1980). Compare with Figure 55. Note wetlands lost during high lake levels, residential development, dredge spoil sites, and highway (M-29) bifurcating marsh.

recreational value of Lake St. Clair, visitors from Michigan and Ontario continue to be attracted to the lake. The lake is readily accessible to the urban areas of metropolitan Detroit and Windsor as well as numerous small urban areas such as Flint, Saginaw, Port Huron, and Sarnia. Lake St. Clair is the most valuable Great Lakes area for non-salmonid sport fish in Michigan. For example, in 1975, nearly half of the total Great Lakes fishing effort was expended on Lake St. Clair (Jaworski and Raphael 1978). Furthermore, fur (muskrat and raccoon) production of the area is among the highest in the State.

With increased commerce in the Great Lakes, a cutoff channel was dredged at South Channel where it debouches into Lake St. Clair. To accomodate Seaway traffic, a 8-m channel was dredged in 1952 through the interdistributary marsh for a distance of 10 km. Seaway Island, a large disposal site now occupies a portion of the interdistributary marsh. To improve recreational boating facilities and mitigate against further erosion, bulkheading and filling along all urbanized shorelines have occurred over the decades. Seawalls extending well above high water levels have replaced the natural levees which extended south from Harsens Island into Lake St. Clair. The number of crevasse channels which transported water, sediment, and nutrients into Muscamoot Bay has decreased.

The degeneration of the St. Clair wetlands follows a historical pattern similar to that of other large wetland complexes in the United States. Initially stimulated by the 1850 swamp acts, agricultural activity occurred. A second significant stimulant was accessibility due to several transportation developments. Inter-urban electric railroads, excursion vessels, and eventually, roads and interstate highways made the wetlands and the shoreline readily accessible. Efficient transport routes have encouraged urban and suburban expansion, changing summer residences to year-round housing.

By contrast, access to the delta and the shoreline of Ontario is more difficult because of the lack of roads. Furthermore, southern Ontario is less populous and much of the eastern portion of the delta is an Indian reserve. These physical and social factors have not encouraged as much wetland loss as seen in Michigan, except at the northern end of Walpole Island which has experienced wetland loss.

With the exception of the electric railroad through St. John's Marsh, wetland losses occurred on the periphery of the resource; that is, modification began at the boundary between the marsh and the adjacent upland. In the St. Clair Delta agriculture was initiated on the premodern surface and gradually expanded southward to the transition (dogwood/meadow) zone and eventually into the shallow interdistributary bays. The natural levees were modified by bulkheading in the 1870s. Filling, aided by bulkheads, extended into the deep interdistributary bays and onto the river shoulders. This pattern of development has continued to the present because wetland boundaries are difficult to ascertain, especially in the Great Lakes where temporary lower lake levels provide a false perception of the position of the shoreline.

Adverse impacts to the artificial (diked wetlands) and 11 natural environments identified in section 4.1 as Lake St. Clair wetlands are shown in Table 35. With the exception of the recently abandoned channels, which are in Ontario, and the transgressive beaches which are generally isolated, all the wetlands have had adverse impacts. Bulkheads and fills have been constructed on the river shoulders, crevasses, and margins of the deep-water interdistributary bays for over a century. To construct roads, spoil was dredged from the landward side of the main channels which inadvertently led to the channelization of the shallow bays. Bulkheads are a common structural feature along many shorelines of the lake and delta and appear to be detrimental to submersed aquatics (Schloesser and Manny 1982). Bulkheads constructed on river shoulders occupy the shallowest portion of the river. Consequently, as dredge and fill occurs, submersed wetlands are displaced lakeward where bottom attachment is more difficult because of stronger currents and greater depths.

Table 35. Adverse impacts to the various morphology types of Lake St. Clair wetlands.

Wetland morphology type	Impact	Example
1. River shoulders	bulkheaded, dredged disposal	South Channel
2. Abandoned river channels	drained, agriculture	Harsens Island
3. Recently abandoned channels	no change	Bassett Channel
4. Crevasse deposits	channelized, bulkheaded	South Channel
5. Shallow interdistributary bays	diked/drained, agriculture, channelized	Harsens Island
6. Deep interdistributary bays	bulkheaded, channelized	Harsens Island
7. Transgressive beaches	minor urban settlement, bulkheaded	Big Muscamoot Bay
8. Shallow shelves	diked, filled, channelized	Mitchell Bay
9. Barrier/lagoon	channelized	North of Thames River
10. Transitional areas	diked, agriculture, filled for residential development	Harsens Island
11. Estuarine/floodbasin	diked/drained, agriculture/urban	St. John's Marsh
12. Diked	diked/drained (originally shelves)	East shoreline (Ontario)

Dredging and Filling

To accommodate recreational boating and commercial shipping, channels to depths of 8 m have been dredged on the perimeter and in the basin of Lake St. Clair. Also there is considerable residential pressure on the shoreline to include the wetlands of the basin. Bulkheading, filling, diking, and disposal of dredged materials have occurred since the early 1900s.

Because of the need for commercial navigation and recreational boating in Lake St. Clair, a significant amount of channel dredging has occurred. The U.S. Army Corps of Engineers, which is responsible for harbor maintenance, has conducted dredging and disposal activities at the Clinton and St. Clair Rivers and the 8 m navigation channel bisecting the lake. In Ontario the Department of Public Works maintains the St. Clair Cutoff Channel and the harbor at Wallaceburg, east of the St. Clair River Delta. To maintain channels at the prescribed depths, the accumulated sediment was normally hydraulically dredged and disposed of in convenient areas such as in designated portions of the open lake.

The volume of materials dredged for Lake St. Clair and the St. Clair River navigation projects is shown on Table 36. Over the 52-year period, about 782,800 m^3 were dredged from U.S. project sites in the two areas. More recent data indicate that from 1971 through 1984 dredging activity in Lake St. Clair totaled 382,300 m^3. The average for the 14-year period is 27,300 m^3 annually which is considerably less than the historical average of 313,200 m^3 for Lake St. Clair. On the Clinton River the 1971-1984 total was 45,000 m^3, which approximates the historic average.

The Ontario maintenance dredging and new work dredging averaged about 195,800 m^3 annually. Most of the dredging in Ontario is confined to the St. Clair Cutoff Channel (182,400 m^3/year).

In 1970 the U.S. Congress enacted Public Law 91-611 (River and Harbor Flood Control Act), which authorized the Corps to construct, operate, and maintain confined disposal sites for containment of polluted dredged spoil in the Great Lakes for a period not to exceed 10 years. At that time, the St. Clair Cutoff Channel and Lake St. Clair sediments were 100% polluted, and the Clinton River was 85% polluted (Raphael et al. 1974). The pollutant was primarily mercury, although the conventional pollutants were also beginning to reach limits set by the U.S.

Table 36. Historical dredging totals of Corps of Engineers projects in Lake St. Clair 1920-1972.[a]

Project	Maintenance dredging (m^3)	New work dredging (m^3)	Total (m^3)	Annual average (m^3)
Channel of Lake St. Clair	2,894,400	13,634,600	16,529,000	317,900
Clinton River	237,400	96,900	334,300	6,400
St. Clair River	3,125,300	20,879,200	24,004,500	461,600
Total	6,257,100	34,610,700	40,867,800	785,900
Average/yr	120,300	665,600	785,900	

[a]Data source: Raphael et al. (1974).

Environmental Protection Agency. To comply with PL 91-611, two confined disposal sites with a combined capacity of 1.5 million m^3 were constructed at the north end of Dickinson Island. Both sites were placed on the premodern surface of the St. Clair Delta. The west site enclosed an area of about 22 hectares and the east site about 48 hectares (U.S. Army Corps of Engineers 1974). In Ontario the St. Clair Cutoff Channel was constructed in the early 1950s to accommodate Seaway traffic along South Channel. The channel was dredged through the interdistributary bay and was linked to the main navigation channel in Lake St. Clair. Dredge spoil was put in a disposal site (Seaway Island) along the east bank of South Channel. The facility covers an area of about 11 km^2, which was primarily colonized with emergent macrophytes typical of an interdistributary bay environment.

Private or contract dredging (under Sec.10 permit of the U. S. River and Harbor Act of 1899) is done by local citizens or homeowners to improve access to Lake St. Clair or to construct boatslips along the lake or the distributaries (Figure 57). The data are not normally tabulated; however, based on our estimates, private dredging volumes probably average about 7,600 to 11,400 m^3 annually. Significant areas of dredging for residential development have occurred

Figure 57. Commercial development in Harsens Island wetland (August 1984).

on the shoreline of Anchor Bay, St. John's Marsh, at the mouth of the Clinton River and along the distributary channels of the delta, particularly North and South channels. Private dredging in Ontario is limited to approach channels for recreational craft in Mitchell Bay and a marina complex near Belle River on the south shore of Lake St. Clair.

Diking

Diking fragments coastal wetlands, separating the managed parcels from the adjacent littoral and upland environments. Generally, as the size of the wetland is diminished, so is the vegetative and wildlife diversity (Larsen 1973). Furthermore, diking of wetlands reduces vegetation diversity because water level controls are established to maintain a particular vegetation type or environmental condition. Stabilizing water levels tends to eliminate those plant species which require low-water periods for regeneration, and promotes dominance of a few tolerant species such as cattail (*Typha* spp.) and woody plants (Keddy and Reznicek 1984).

The hydrologic isolation of diked systems is reflected in their greatly reduced fish use and simplified invertebrate communities, particularly where winter ice and summer temperatures reduce dissolved oxygen and otherwise reduce the water quality. The effect of earthen dikes on waterfowl migration, other wildlife movements, and predation is not well known. However, Dennis and North (1981) have shown a dramatic decline in the use of the Lake St. Clair marshes by true marsh-dwelling species such as the American wigeon (*Anas americana*), gadwall (*Anas strepera*), green-winged teal (*Anas crecca*), and wood duck (*Aix sponsa*). From 1968-69 to 1976-77 the use by these dabbling ducks declined by 73% during the spring period. Autumn marsh use also declined by 40%. However, the investigators noted that spring use generally provides a better indication of the value of the wetlands to migrant waterfowl since the management techniques which were used during the fall hunting seasons are not implemented during the spring.

Toxic Substances

Discovery of mercury contamination in the St. Clair River-Lake St. Clair-Detroit River-Lake Erie system in 1970 generated great public interest in the mercury levels of water and fish. Subsequent banning of sport and commercial fishing led to testing for trace mercury by various State and Federal agencies to define the extent of the pollution and to determine its major sources. Two chemical plants, Dow Chemical Corporation, Sarnia, Ontario, and BASF Wyandotte Chemical Corporation, Wyandotte, Michigan, were identified as major contributors to the mercury pollution of Lake St. Clair and Lake Erie (Walters et al. 1974). These companies manufactured chlorine gas and caustic soda by the electrolytic process, which involves the electrolysis of brine to produce chlorine gas and a mercury-sodium metal amalgam. The amalgam is contacted with water to produce sodium hydroxide, the mercury metal being recycled to the electrolytic cell. The rate of accidental mercury release from these two plants has been estimated to be 25 kg per day from 1950 to 1970 for the Dow Chemical plant and 5 to 10 kg per day from 1939 to 1970 for the BASF Wyandotte plant (Federal Water Quality Administration 1970).

Walters et al. (1974) calculated that 228 metric tons of mercury pollution had been loaded to the top 20 cm of western Lake Erie sediment during the period 1939 to 1971. Sediment cores taken at the mouth of the Detroit River and western Lake Erie yielded surface mercury values up to 3.8 ppm which generally decreased in concentration exponentially with depth (Figure 58). Several years after the chlor-alkali plants diminished operation the area was again cored (Wilson and Walters 1978) with analyses showing that recent deposits covered the highly contaminated sediment with a thin layer of new material which had mercury concentrations approaching background levels (0.6 ppm). As a result of these discharges, mercury in fish of Lake St. Clair and western Lake Erie was a major contaminant problem in the early 1970s. Levels of total mercury in walleye (*Stizostedion v. vitreum*) collected from

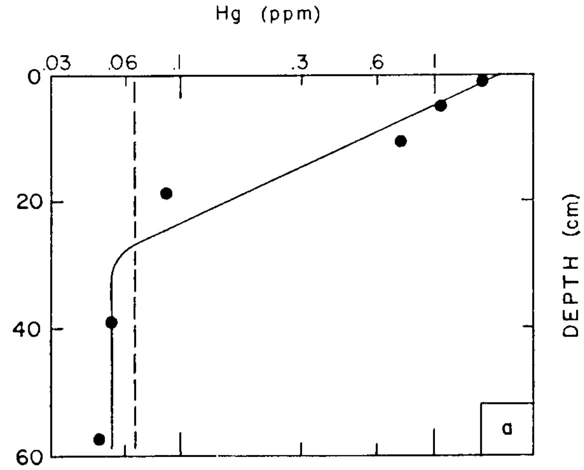

Figure 58. Mercury concentration in sediment core from western Lake Erie near mouth of Detroit River (Walters et al. 1974). Note mercury-enriched surface zone overlying sediment having natural background mercury levels (dashed line).

Lake St. Clair have declined from over 2 ug/g in 1970 to 0.5 ug/g in 1980. In western Lake Erie, 1968 levels of mercury were 0.84 ug/g as compared to only 0.31 ug/g in 1976. The rapid environmental response subsequent to the cessation of the point source discharges at Sarnia, Ontario, and Wyandotte, Michigan, can be attributed to rapid flushing of the St. Clair-Detroit River system, the high load of suspended sediment delivered to western Lake Erie, and the high rate of productivity (International Joint Commission 1981).

Mudroch and Capobianco (1978) studied the relationship between the concentration of seven metals in sediment and marshwater, and uptake of these metals by emergent, submersed, and floating-leaved plants growing in wetlands located on the east shore of Lake St. Clair. They found a high correlation between metals and organic carbon contents in the sediments. The accumulation of metals in plants varied from species to species (Table 37) and showed a complex relationship with metal concentrations in the sediment. Water-milfoil (*Myriophyllum* spp.) and pondweed (*Chara* spp.) accumulated more metal than the other aquatic plants.

Table 37. Metals concentrations in living plant tissues from Big Point Marsh, Ontario on Lake St. Clair.[a]

Species	Metals (ppm) Pb	Zn	Cr	Ni	Cd	Co	Cu
Myriophyllum heterophyllum	18.3	18.6	6.0	7.4	1.3	5.6	4.9
Chara sp.	35.1	15.0	4.5	10.9	3.2	12.8	5.3
Nymphaea odorata	4.0	14.0	<1.0	2.1	<1.0	1.7	1.9
Pontederia cordata	4.5	18.3	2.4	1.6	<1.0	1.1	2.1
Typha latifolia	3.8	11.5	1.6	2.1	<1.0	1.3	1.3
Lythrum salicaria	8.5	25.0	1.7	3.0	<1.0	1.7	3.7
Carex lacustris	3.6	25.5	1.3	1.2	<1.0	1.8	2.4

[a]Data source: Mudroch and Capobianco (1978).

Metal concentrations in roots of broad-leaved cattail (*Typha latifolia*), purple loosestrife (*Lythrum salicaria*), and pickerel weed (*Pontederia cordata*) were found to be higher than in the aboveground biomass. The metals taken up by marsh flora are retained in the tissues and after decay they become a part of the marsh surface sediment.

Wetland Loss

Jaworski and Raphael (1976) compiled comprehensive data on wetland loss for the Michigan side of Lake St. Clair. In 1873 the U.S. portion of Lake St. Clair supported 7,274 hectares of wetland vegetation (Table 38). By 1973 this habitat had dwindled to 2,020 hectares. Significant losses not only occurred on the St. Clair Delta and St. John's Marsh but on the entire margin of the lake as well. Gaukler Point at the head of the Detroit River was colonized with 187 hectares of wetlands and the Clinton River had over 1,295 hectares of habitat at its mouth and its flood basin. Some coastal areas, particularly north of the Clinton River appear to have been drained for agriculture in the 1860s suggesting that the 1868-1873 data represent minimum rather than maximum wetland acreage.

In contrast to Michigan's wetlands being lost to the ongoing urbanization, Ontario wetlands are being lost to agriculture. The wetlands from the Thames River north to Chenal Ecarte dwindled from about 3,600 hectares in 1965 to 2,900 hectares in 1970 (McCullough 1982). About 700 hectares or nearly 20% of the privately owned resource base was lost over the 5-year period. Figure 59 and Table 38 reveal specific areas of wetland loss of the coastal Ontario wetlands excluding the Walpole Island Indian Reserve. Draining for agricultural use has accounted for 91% of the wetland loss whereas marina and cottage development has consumed 9% of the resource. Clearly, urban pressure is presently a problem in Michigan and agriculture pressure a problem in coastal Ontario.

Although the Ontario shore of Lake St. Clair is low lying and subject to flooding, erosion has only been identified as a hazard from the Thames River westward (Boulden 1975). This suggests that permanent loss of wetland habitat north of the Thames River is due to human intervention. During the record high lake level in the early 1970s, about 1,000 hectares of emergent shoreline marsh from Mitchell Bay southward to the Thames River were temporarily lost (McCullough 1982). This loss was tempered in part by the flooding of transition vegetation which occurred on the upland (east) margin of the wetlands. Similarly the delta and Anchor Bay are subject to flooding, though erosion is not identified as a serious problem (Great Lakes Basin Commission

Table 38. Michigan and Ontario wetland losses on Lake St. Clair.[a]

Michigan location	Wetland area 1868-73 (ha)	1973 (ha)	Loss (ha)
St. Clair Flats	5,473	1,779	3,694
Swan Creek	75	2	73
Marsac Point	61	2	59
New Baltimore	21	0	21
Salt River	162	18	144
Clinton River	1,295	221	1,074
Gaukler Point	187	0	187
Total	7,274	2,022	5,252

Ontario location	1965 to 1973 Area loss (ha)	Wetland type	Cause
Thames River	59	diked	agriculture
Thames River mouth	74	open	marine/cottage construction
Bradley Marsh	327	diked	agriculture
Balmoral Marsh	11	diked	agriculture
Snake Island Marsh	156	diked	agriculture
St. Lukes Bay	22	diked	agriculture
Patricks Cove	59	diked	agriculture
Mitchell Bay	7	diked	agriculture
Mud Creek Marsh	167	diked	agriculture
Total	882		

[a]Data sources: Jaworski and Raphael (1976), McCullough (1982).

1975). The recent losses here are due to diking and/or filling, in most instances, for urban growth.

The wetlands of Lake St. Clair have been mapped from older navigation charts and recent topographic maps (Figure 60). This figure illustrates significant losses between 1873 and 1968 on the periphery of the lake. However, the most apparent impacts are evident in the Clinton River, the St. Clair Delta, and the eastern shore of the lake. It is evident that the wetlands in all three areas have been modified along their margins. The wetlands on the eastern shoreline were approximately 2.5 km wide. Since 1873 they have been impacted from the landward side and are now about 0.8 km in width. The progression of losses in the St. Clair Delta follows a similar geographic pattern. The losses in both areas were initially stimulated by agriculture. In the Clinton River area, wetland losses occurred from both the landward as well as the lakeward boundary. Fundamentally, an isolated wetland has been created.

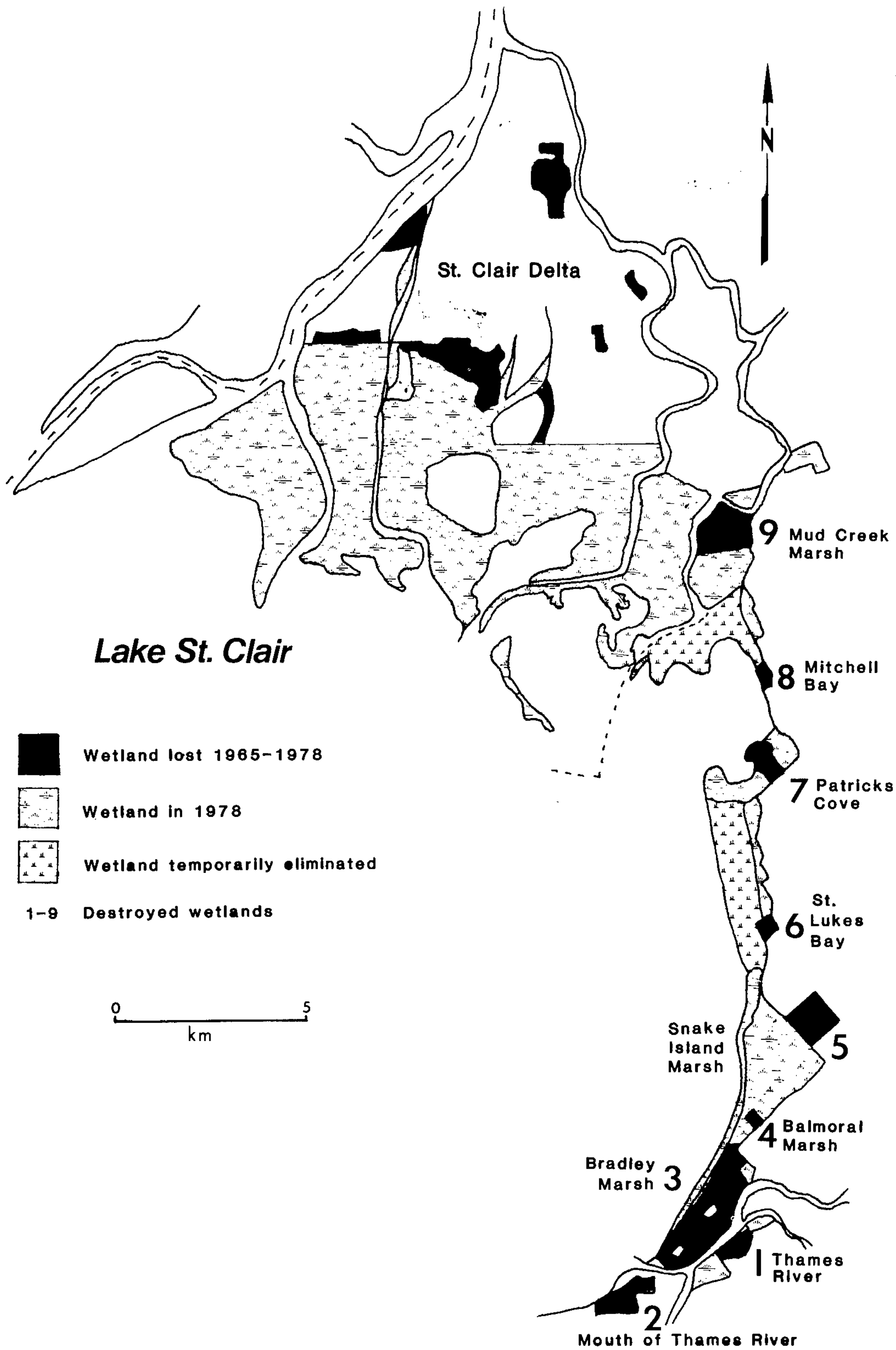

Figure 59. Wetland losses along the Ontario shoreline of Lake St. Clair (McCullough 1982).

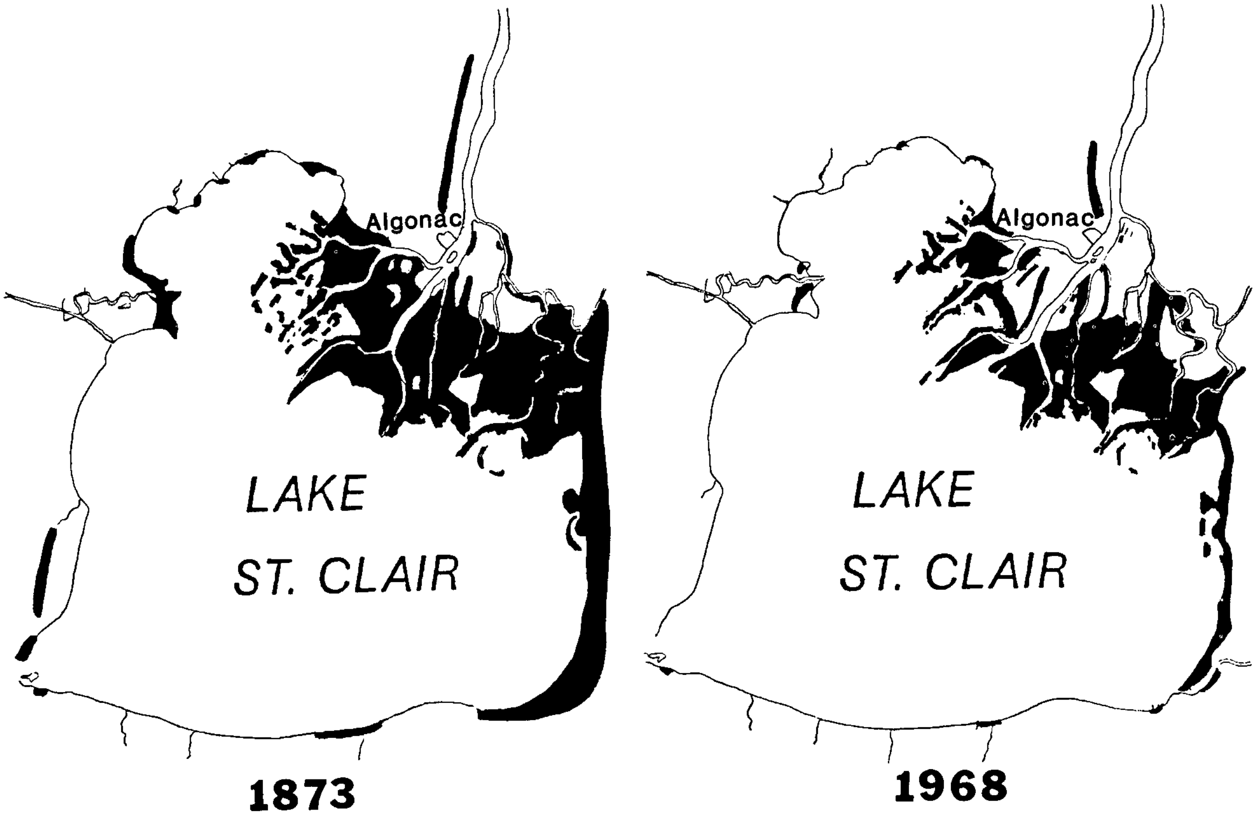

Figure 60. Comparison of Lake St. Clair coastal wetlands distribution in 1873 and 1968.

Table 39 represents a summary of wetland losses in Lake St. Clair. Since the topographic quadrangles and the navigation charts only display emergent wetlands, the area values of submergent aquatics were estimated. The relative losses between the historical periods are evident. The losses on Table 39 are greater than that noted by Jaworski and Raphael (1976) because their data did not include what is now surmised to be submersed vegetation. The percentage of wetland area lost in Michigan is greater than in Ontario (45% vs. 34%), but the actual area lost in Ontario exceeds that lost in Michigan. In Michigan as well as in Ontario, more of the wetland base was lost along the shorelines than in the delta. Since the coastal zone wetlands are parallel to Lake St. Clair, their accessibility plays an important role in their modification. The St. Clair Delta conversely projects into Lake St. Clair, limiting accessibility and hence adverse impacts. It should not be inferred from the data that the wetland quality and diversity have not changed over the 95-year period. In sum, 9,136 hectares of the resource base have been lost.

<u>Summary</u>

Both natural disturbances, such as water-level fluctuations (as the Great Lakes water levels oscillate) as well as cultural disturbances (e.g., diking) affect the wetland ecosystems. As reflected in Eugene Odum's "pulse stability concept," some of these disturbances can be beneficial. In this section, however, the impacts of adverse cultural effects have been reviewed. Of particular concern are the following: 1) wetland loss, 2) diking, fragmentation, and loss of hydrologic connectivity, and 3) changes in the environmental gradient and plant communities.

Table 39. Comparison of 1873 and 1968 Lake St. Clair wetland areas.

Location	Area (ha)					
	Michigan		Ontario		Total	
	1873	1968	1873	1968	1873	1968
St. Clair Delta	5,414	3,077	9,641	7,234	15,055	10,311
Clinton River	1,192	248	--	--	1,192	248
Remaining Mich. shoreline	1,900	806	--	--	1,900	806
Remaining Ontario shoreline	--	--	4,219	1,862	4,219	1,862
Total	7,506	4,131	13,860	9,096	22,366	13,227

As discussed in this section, during the period 1873-1968, approximately 9,136 hectares of coastal wetlands have been lost. This amounts to a 41% reduction in the original coastal wetland resource base of Lake St. Clair. The greatest percentage loss has been on the American side and the greatest area loss on the Canadian side. More wetlands have been destroyed along the shorelines than in the delta. In addition, except for Dickinson Island and St. John's Marsh, the upper zones (i.e., the sedge marsh-shrub-swamp fringe) were converted to other land uses. The juxtaposition of corn fields and diked cattail marshes on St. Anne Island is a case in point. At present, nearly half of these extant wetlands along Lake St. Clair consist of cattail communities.

Loss of coastal wetlands along the Michigan side of Lake St. Clair results in a loss of wetland function and value. For example, public drains installed to improve runoff now occupy former creek channels, which no longer benefit from the flood water storage, sediment trapping, and nutrient uptake afforded by the natural wetlands. Nor do the remaining wetlands along the river mouths and shorelines, which have been reduced in size, partially developed (especially on the lakeward side), and otherwise impacted, have the fish and wildlife values they once had.

Approximately one-half of the remaining coastal wetlands, i.e., 5,280 hectares, in the St. Clair Delta are now diked. This includes St. John's Marsh, which is isolated from Lake St. Clair by earthen berms, but is not subject to water level controls. With the exception of St. John's Marsh, the upper part of the St. Clair Flats State Game Area, and a few other small parcels, over 75% of the diked wetlands are colonized by cattails and associated submersed aquatic communities. The phrase "diked cattail marshes" is indeed appropriate. What is important here is that it is the remaining open-system wetlands which are contributing to fish production, wildlife habitat, and diving duck feeding of Lake St. Clair. In contrast, the diked wetlands provide more of a single purpose - that of attracting dabbling ducks, especially mallards for waterfowl hunters.

The adverse impact of isolating and fragmenting wetlands by means of roadbeds, canals, earthen dikes, and other developments appears not to be fully recognized. For example, many conservationists in Michigan are advocating the preservation of St. John's Marsh, but few call for an increase in its hydrologic connectivity to Lake St. Clair. Moreover, unless a wetland is physically destroyed, not merely fragmented, most wetland researchers would not refer to an isolated wetland as being "lost."

Current coastal development not only results in fragmentation and loss of

hydrologic connectivity, but also frequently is associated with the loss of upper plant communities (Jaworski and Raphael 1976). Therefore, most of these extant wetlands consist of just cattail and submersed aquatic communities, rather than a complete wetland community continuum. Changing of water levels in the Great Lakes will, then, result in the loss of the current function in a given wetland as opposed to the shift of this function laterally in accord with the vegetation movements. In contrast, as exemplified by Dickinson Island, wetlands which are connected directly to Lake St. Clair and exhibit a full environmental gradient, tend to experience lateral shifts in function and values. Furthermore, they are maintained at little or no cost to the public.

Small, isolated wetlands near developments such as suburban housing, marinas, etc., exhibit proximity and off-site impacts. Proximity impacts include ambient noise levels as well as human and pet intrusions. Off-site affects center on nutrient and sediment loading resulting from wind and water transport mechanisms. If the extant parcel of wetland is zoned for residential or some other intensive use, there are pressures for filling and development. Fire, as a disturbance, seems to be limited to the cattail and sedge marshes of Dickinson Island (Jaworski et al. 1979).

5.2 WETLAND OWNERSHIP AND MANAGEMENT

Wetland Ownership

Wetland ownership is in the hands of individuals as well as State, provincial and Federal agencies. The management of the wetlands by these groups follows diverse strategies. The current ownership of the coastal wetlands as well as the zoning and long-range plans will strongly affect the future use of these environments. In this section, an attempt has been made to project the future land use of these areas, and by using those projections, address the issues of management, restoration, and artificial construction of wetlands.

As indicated in Appendix M and on Figure 61, most of the ownership of the larger, extant coastal wetlands lies in public hands. Exceptions are St. John's Marsh, which the State of Michigan is attempting to purchase from the remaining private owners, and Walpole Island, Ontario, which forms an Indian Reserve. Many of the undiked coastal wetlands on the Canadian side of the St. Clair Delta are owned by the Province of Ontario, with the exception of Walpole Island. Canada's Department of the Environment (DOE) owns the Lake St. Clair National Wildlife Area, whereas Ducks Unlimited has ownership of diked marshes south of Mitchell Bay.

The land ownership of the Michigan portion of the delta is shown in Figure 62. Two open water parcels, i.e., Units A and B of the St. Clair Waterfowl Refuge,

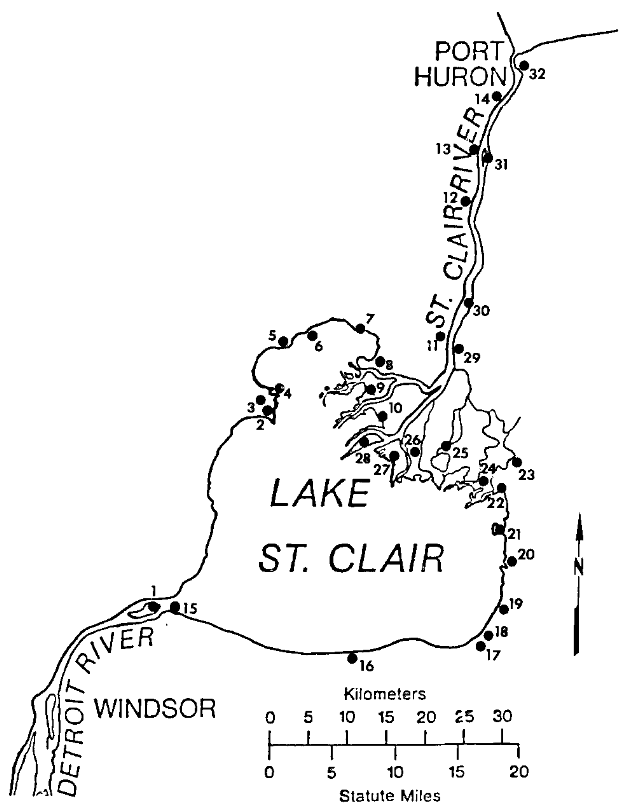

Figure 61. Location map of individual coastal wetlands of the St. Clair River-Lake St. Clair ecosystem; characteristics and ownership of each wetland are given in Appendix M.

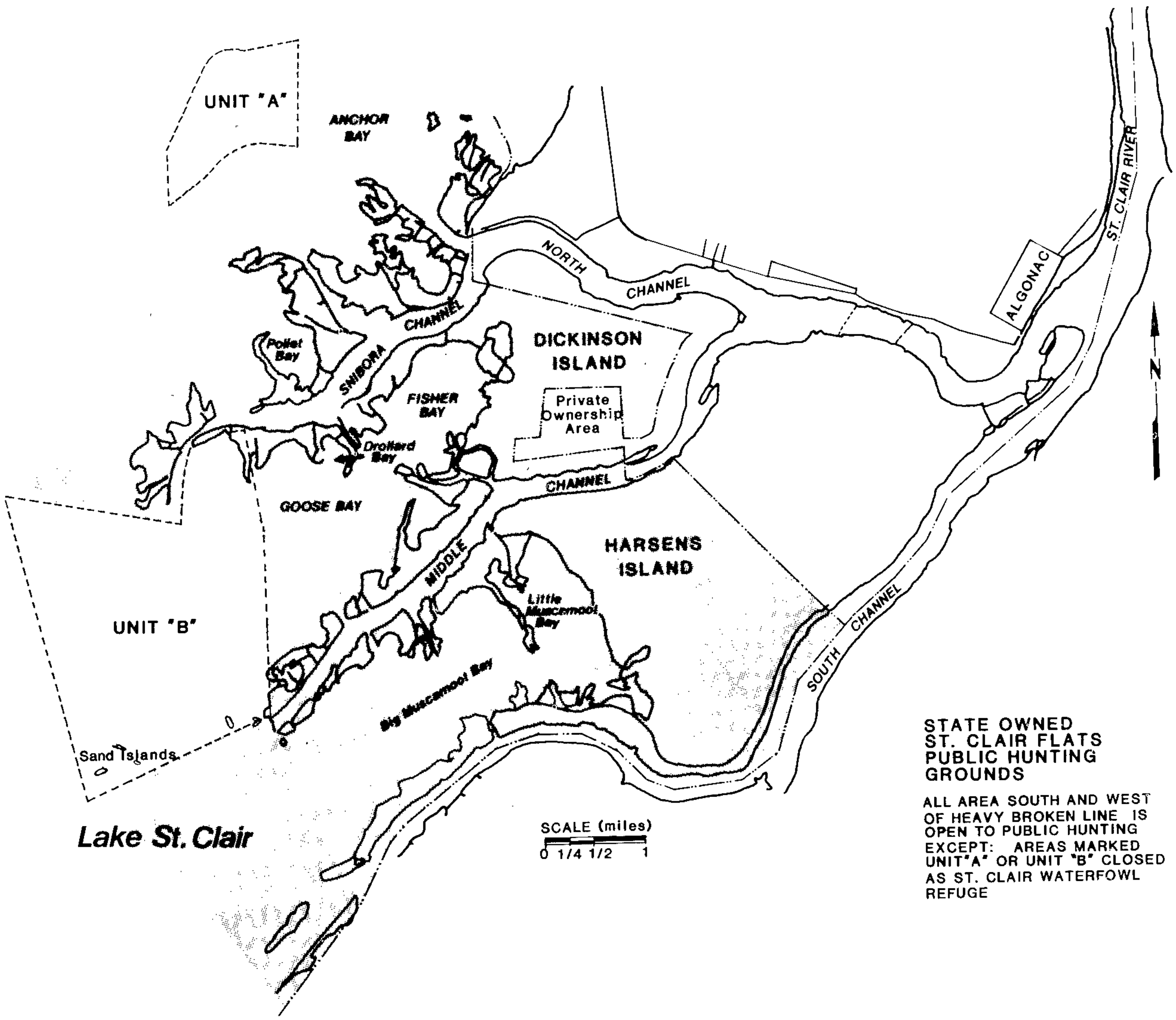

Figure 62. Ownership map of the Michigan portion of the St. Clair Delta.

are administered by the Michigan DNR. Approximately 40% of Dickinson Island is in private ownership, especially the northern and eastern shores as well as a block in the south-central area. In addition, the U.S. Army Corps of Engineers manages two disposal sites on Dickinson Island along North Channel, and there are private bottomland patents along the distributary channels of both Dickinson and Harsens Islands. Although the Department of Natural Resources is slowing the residential and summer home development along these distributary channels, the land remains in private ownership. At present, the lower part of Harsens Island, and much of Dickinson Island, and those unpatented wetlands and adjacent shallow-water bottomlands would be considered part of Michigan's St. Clair Flats State Game Area. Ownership of the small, undiked wetland parcels scattered along Anchor Bay and along the western, eastern, and southern shores of Lake St. Clair is generally private.

Wetland Management

At present, in the delta there are two basic management strategies: 1) natural and 2) managed for waterfowl hunting and perhaps breeding as well. The

publicly owned, open wetland systems are natural, responding to seasonal and long-term water level fluctuations. In comparison, the diked wetlands consist largely of cattail marshes that are managed by means of electric pumps, flood gates and weirs. In several managed marshes, crops are grown, then flooded to facilitate waterfowl feeding.

No significant changes in the wetland management practices are anticipated. It is expected that the status quo will generally continue. Further diking of wetlands is strongly discouraged because of the adverse impacts discussed earlier. With regard to the management of the currently diked areas, it is recommended that waterfowl breeding be encouraged in all of the contained marshlands by means of nesting platforms and areas. Moreover, to facilitate fish use, perhaps the wetlands could be opened up during the spring spawning season or at least during those years when no water-level manipulation is necessary for waterfowl management. Creating artificial islands and allowing better-drained areas to revert to shrub or meadow communities may also add diversity.

Other practices, such as experimental marsh burning, have improved the waterfowl loafing population in Ontario's diked wetlands (Ball 1984). Fertilization however, is not recommended at this time. Wherever possible, hydrologic connectivity should be increased.

Dickinson Island, because of its open system nature and intact environment gradients, must be managed separately as it may well be the most valuable coastal wetland in the Great Lakes region. Keeping it an open system, with only passive recreation permitted, will insure its multiple functions for fish, waterfowl, other wildlife, and food chain support. Once filled, the confined disposal sites may be used for wildlife, but not for a theme park as suggested by some local residents. The provision of public utilities, on either Dickinson or Harsens Islands, would initiate uncontrolled development pressures.

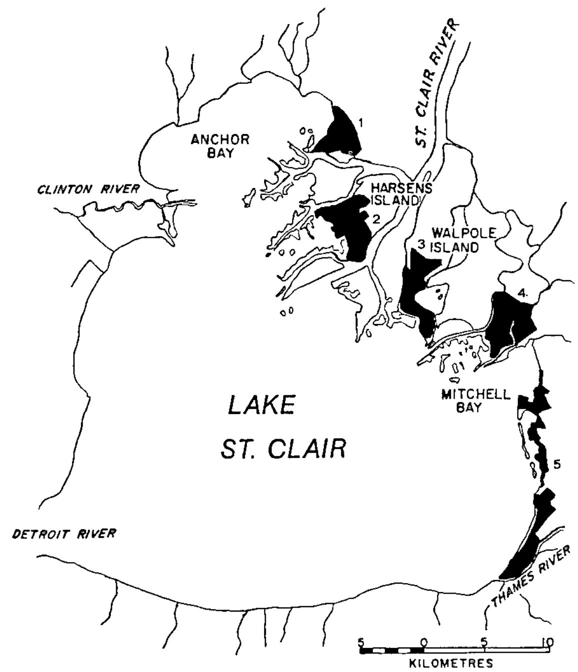

Figure 63. Location map of Lake St. Clair diked coastal wetlands (see text for explanation of numbers).

Diking and Management. As indicated in Figure 63, several large areas of the St. Clair Delta wetlands are diked: St. John's Marsh (no. 1), lower Harsens Island (no. 2), lower Walpole Island near Goose Lake (no. 3), lower St. Anne Island (no. 4), and Mitchell Bay-Thames River mouth region (no. 5). Nearly one-half of the total delta wetlands, some 5,280 hectares, are separated from Lake St. Clair by earthen dikes. Most of these diked environments occur in zones where cattails naturally grow and elevations range between 175 and 176 m above International Great Lakes datum.

Except for the wetlands in St. John's Marsh and those along western Lake St. Clair, most of these diked marshlands are managed for waterfowl purposes. Diking and water-level manipulation of wetlands for the benefit of waterfowl hunters is a traditional practice in the Great Lakes region among both private and public shooting clubs. The earthen dikes impound water inside the marshlands during low-water periods in the Great Lakes, but also function to protect the marsh from erosion

and excessive high water during above-average lake level conditions. The St. Clair Flats State Game Area, Canada Club, and the Ste. Anne Club marshes are among the venerable diked wetlands managed for waterfowl hunting during the fall migration.

St. John's Marsh, which straddles Highway M-29 in Clay Township, is included as a diked wetland because the line of houses and access road along Bouvier Bay (of Lake St. Clair) hydrologically separate it from Lake St. Clair (Figure 56). Approximately 217 hectares of diked marshlands are situated west of highway M-29, and about 478 hectares lie east of this roadway. Interior dikes and the roadbed with only one bridge (or culvert) further fragment this wetland and preclude water exchange. Although there are five openings to Bouvier Bay, water exchange and fish access are limited.

Much of lower Harsens Island is contained within the St. Clair Flats State Game Area (1,085 hectares) and is managed by Michigan DNR as a public waterfowl hunting facility. In the upper section, which consists of 515 hectares, crops such as corn are grown and flooded in fall to attract migratory waterfowl. The more lakeward portion of the game area is essentially a water-level controlled cattail marsh which provides cover and some breeding habitat for the waterfowl. During the 1974-75 waterfowl hunt, 76% of the harvest from the 60 blinds on the game area consisted of mallard along with lesser numbers of black duck, pintail, green-winged teal, and American wigeon (Jaworski and Raphael 1978).

In Ontario, diking is commonly practiced (Table 38). As shown on Figure 63, diked area no. 3 consists of three diked systems located on lower Walpole Island. The area of these diked marshlands totals 1,097 hectares. Cattails and submerged aquatics appear to dominate the vegetation. Some of the wetlands of the northernmost diked area are now being utilized for cultivated crops.

Diked area no. 4 on Figure 63 refers to two diked systems on lower St. Anne Island. The diked area located on the west side of Chenal Ecarte consists of 660 hectares, whereas the diked system on the east side is comprised of 415 hectares. Aerial photographs indicate dense colonies of cattails in these managed wetlands, with few canals or other human disturbances. The most lakeward diked wetland on lower Walpole Island also has few canals across it. Pumping stations and flood gates or weirs are employed to manage water levels here and at the other waterfowl shooting club marshes.

Along eastern Lake St. Clair many of the coastal wetlands are diked. Diking is done by the local farmers who wish to cultivate as close to Lake St. Clair as possible. In addition, at Mitchell Point there is a managed wetland, and two more exist near the mouth of the Thames River. The areas of these three diked systems are: 194 hectares, 393 hectares, and 500 hectares. The latter two are designated as Area IV and Area III, respectively, on the Tilbury (Ontario) Quadrangle. Moreover, east of Area IV, there is a 156-hectare, square-shaped diked area. A total of 1,329 hectares were planimetered on current maps of this coast. Cattails appear to be the dominant vegetation type.

The adverse impacts of diking coastal wetlands are poorly understood. Nevertheless, several adverse impacts include: 1) loss of fishery function, 2) blockage of water exchange, 3) loss of food chain support, 4) fragmentation and isolation of diked wetlands, and 5) lower diversity and water quality of diked areas. Loss of fish habitat and associated fishery functions is perhaps the principal adverse impact of coastal wetland diking. Diking has long been a source of conflict between waterfowl- and fishery-resource managers. Clearly, most fish, with the exception of extremely tolerant species such as carp and bullheads, do not spawn in diked wetlands. Furthermore, larval and juvenile fish cannot easily disperse into nor tolerate the fluctuating water temperatures and water quality of these contained systems. The authors have noticed that predator fish tend to forage only in those coastal wetlands where lake water masses invade the open wetlands. For example, on Dickinson Island one may observe largemouth bass and bluegills only

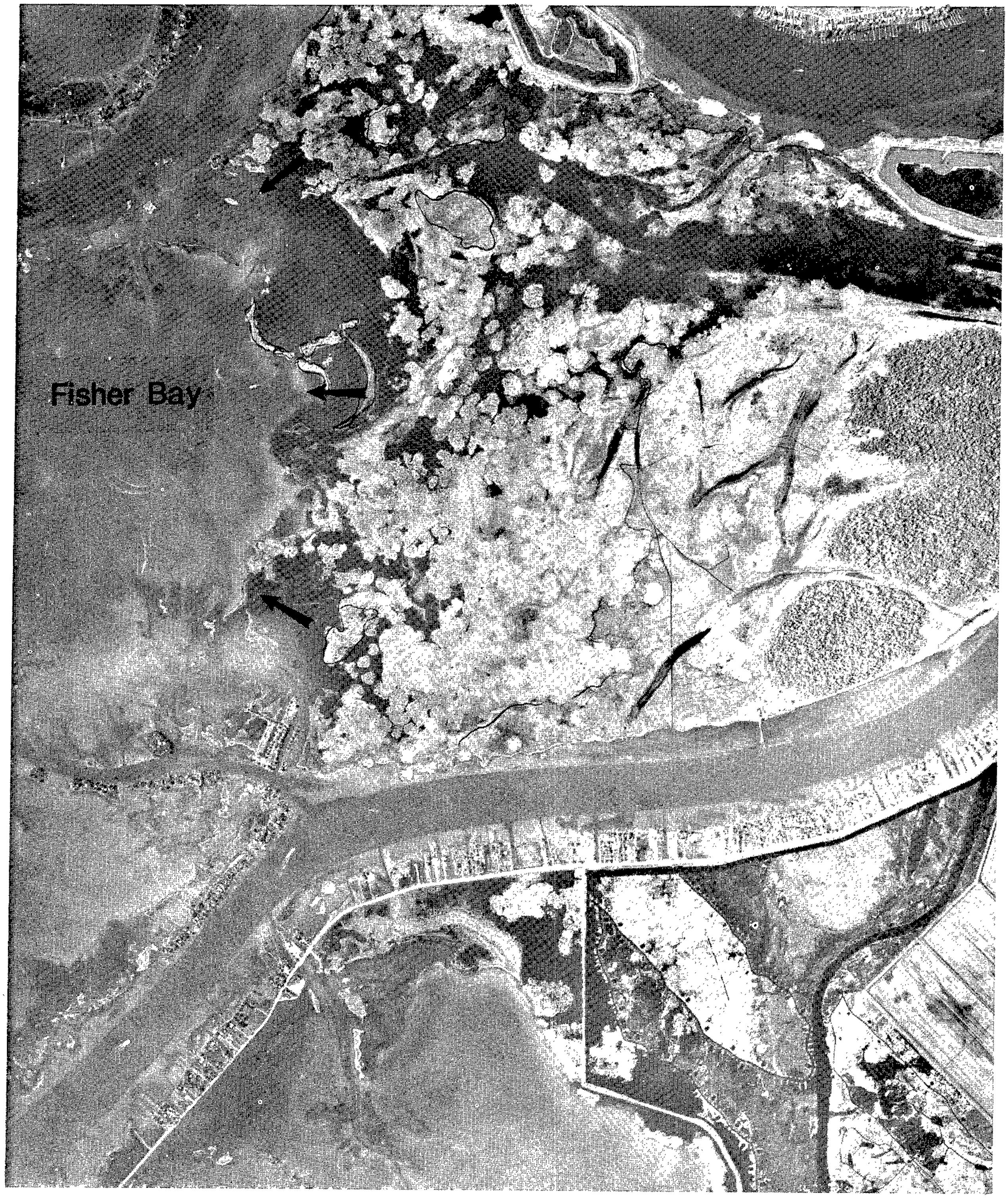

Figure 64. Aerial photograph of Dickinson Island wetlands, St. Clair Delta (May 1980). Note drainage from the coastal marshes to Fisher Bay (left side). North Channel is at the top and Middle Channel is at the bottom of the photograph.

in circulating marsh waters, particularly near culverts, or where lake water masses prevail.

Diking prevents water exchange between the wetland and the adjacent water body. Thus, the waters of the canals and open-water areas of the contained sites stagnate, cover with film, and exhibit large diurnal temperature ranges (Mudroch and Capobianco 1978). Although the dissolved oxygen levels in the diked wetlands remain above 75% saturation (Figure 22), in response to atmospheric diffusion and photosynthetic activity, excessive daytime water temperatures in summer reduce the dissolved oxygen concentrations to critical levels. During the cold winter months with abundant snow cover, oxygen depletion may occur under the ice cover, resulting in fish kills and die-off of invertebrates.

Although no definitive research has been conducted which explains the exceptional fish production in Lake St. Clair (Hatcher 1982), it is believed that the wetlands are important in the food webs. The St. Clair Delta wetlands are important sources of nutrients, particulate organic matter, phytoplankton, small zooplankton, and drift organisms. Zooplankters probably filter the preferred food items out of the marsh drainage. Figure 64 illustrates drainage from the delta wetlands. Leach (1980) found that the waters from the main channels of the St. Clair River are lower in nutrients than the waters derived from the tributaries on the Canadian side of the delta. Because Chenal Ecarte and the other Ontario tributaries incorporate considerable flow from the adjacent wetlands, it is felt that these waters contain important quantities of nutrients, detritus, and living matter for the food webs of Lake St. Clair.

Poe (1983) attempted to demonstrate the relationship of the aquatic macrophytes and associated periphyton to the fish production of Lake St. Clair. In spite of some positive relationships established in some sampling stations, Poe's data for Muscamoot Bay seemed contradictory. Sampling of Muscamoot Bay revealed that macrophyte-free areas had higher numbers of macrophytoplankton and zooplankton, and yellow perch caught over macrophyte-free areas contained higher numbers of these invertebrates than did fish caught over macrophyte areas. The paradox in these data may be explained by marsh drainage which is associated with large numbers of filter-feeding zooplankton and yellow perch regardless of the occurrence of vegetated substrates.

Wetland restoration. Only two areas of coastal wetland are identified for restoration. First, the function and value of St. John's Marsh could be increased with improved hydrologic connectivity (Figure 56). It is recommended that the culverts connecting this wetland to Bouvier Bay be enlarged to facilitate greater water mass exchange. Also, water exchange across M-29 could be improved with the addition of another large culvert close to Pearl Beach. Additionally, the water quality near the Perch Isle Point subdivision should be monitored, and some of the interior dikes west of M-29 should be breached or removed.

Secondly, the fragmented wetland complex south of the Clinton River Estuary should be restored (Figure 54). Perhaps this area should be comprehensively planned since a private developer has already attempted to construct subdivisions in that area. The Detroit District Corps of Engineers refers to this threatened wetland as Verchev's Marsh. A comprehensive plan which includes the function of the Black Creek, the impact of the Metropolitan Beach development, and connectivity to Lake St. Clair is suggested. Restoration of a wetland on this western side of Lake St. Clair could partially mitigate the historic wetland losses in this coastal stretch. Moreover, certain fish such as northern pike and largemouth bass require spawning habitat distributed every 8 to 16 km along a coast because they are not long-distance migrants (Jaworski and Raphael 1978).

Artificial construction. No artificial construction of wetlands is recommended at this time because the current wetlands appear adequate and Lake St. Clair is very productive. If the current wetland resource base can be

conserved and/or improved, then the present ecology of the lake may well be assured.

Management options. Wetlands perform valuable functions for shoreline municipalities. They provide habitats for desired plants and animals, they filter pollutants and sediments from storm drainage, and they protect coastal structures from wave attack. On the other hand, wetlands are often barriers to lake access and therefore are susceptible to filling, dredging, and development, which in turn impairs their natural functions.

The important functions of wetlands are often disregarded by those wishing to develop an area. The State of Michigan has recognized this and has formulated policy to protect wetlands. The Shorelands Protection and Management Act of 1970, provides programs which include the protection of wetlands in the Great Lakes shorelands. At the local level, a special problem facing decision-makers is the identification and regulation of adequate buffer areas surrounding the designated wetlands.

In Michigan, once "areas of concern" have been established, the level of control must be determined. Special use permits and lists of acceptable construction near wetlands provide a method of minimizing wetland disturbance by permitting only those activities which contribute least to change. Wetlands are unsuitable for most kinds of development. Disruptive dredging and filling are often necessary to create a usable area for the construction of buildings, parking areas, and access roads. On-site sanitary sewage treatment is difficult because of poor percolation and the high water table. Recreation uses can be developed around wetlands in a manner compatible with natural systems. Camping, canoeing, and nature trails make use of the water recreational value of wetlands. With such precautions, construction need not cause excessive damage.

5.3. PROSPECTS FOR THE FUTURE

The freshwater wetlands along Lake St. Clair will continue to constitute important ecological communities. These coastal wetlands, particularly the St. Clair Delta wetlands, have had and should continue to have significant functions in the Lake St. Clair ecosystem. Conclusions in this section are based on physical, biological, economic, and political factors.

The recent history of the Lake St. Clair wetlands is characterized by relative stability as well as high function and value. Given the general degradation which has taken place in the lower Great Lakes during the past several decades, the future prospects for the coastal wetlands along Lake St. Clair are reasonably bright. As coastal wetlands in adjacent lakes diminish, the relative importance of the Lake St. Clair wetlands is increasing. Although there has been a 41% loss in the Lake St. Clair wetlands, and 50% of the extant wetlands are diked, the delta wetlands have not suffered degradation comparable to that of Green Bay, Saginaw Bay, and western Lake Erie.

The physical framework of Lake St. Clair wetlands partially explains the high productivity of these wetlands. First, the total area of coastal wetlands is large in comparison to the relatively small size of Lake St. Clair. Second, these deltaic wetlands are distributed over a large area of the northern part of the lake. Third, physical diversity facilitates multiple subsystems. This creates numerous aquatic habitat and coastal wetland interfaces which are located in remote areas and thus buffered from cultural impacts. In addition, the St. Clair Delta is geologically stable. Subsidence is not occurring and delta extension or erosion have not been significant over the last century.

On the ecosystem level, as well as on a local habitat scale, the hydrology and hydrologic connectivity of the St. Clair Delta wetlands are most favorable. Relatively cool, highly-oxygenated, and non-turbid waters enter from Lake Huron and pass through the deltaic wetlands. The distributaries and crevasse channels (locally called "highways") distribute this high-quality input water throughout the wetlands. For example, an abandoned distributary channel permits water flow

across the entire length of Dickinson Island. Given a residence time of only 7 to 9 days in Lake St. Clair, circulation is well established and little stagnation occurs. Water exchange between the lake and coastal wetlands is also facilitated by seiches.

The well-known turbidity problems of other coastal wetland systems, such as Green Bay and Saginaw Bay, are not a major adverse impact in the Lake St. Clair wetlands. Siltation and turbidity are low in the deltaic wetlands because the St. Clair River has a very low suspended load and the bedload consists of fine sand. Some local turbidity occurs at the mouth of the Clinton and Thames Rivers during spring runoff and flooding. Also, within Lake St. Clair, resuspension of bottom sediments, as in Anchor Bay during storms, can discolor the water over large areas.

Wetland erosion is not a problem along Lake St. Clair due to the relatively short fetch and shallowness of the lake basin. Coastal erosion resulting from eustatically rising water levels and from long-term lake level fluctuations is not a significant problem as it is in Lake Erie. Because the deltaic wetlands are largely open systems that slope lakeward, lake level oscillations do not result in wetland die-back or senescence as is true in many other coastal wetland systems. Rather, Lake St. Clair wetlands shift up or down the gradient, maintaining their productivity at various lake levels. Dickinson Island is an excellent example.

Biologically, these coastal wetlands exhibit relatively high habitat and species diversity. Productivity in St. Clair Delta wetlands is also high. Such conditions manifest themselves in surplus waterfowl foods and impressive fish catches. Open wetlands systems, with complete environmental gradients and numerous ecotones, exhibit "pulse" stability and high productivity. Although further research is needed to define the importance of the flux of particulate organic matter, drift organisms, and other organic foods from the wetlands into Lake St. Clair, there is an apparent association of waterfowl, game fish, and other wildlife with these wetland discharges. The high dissolved oxygen levels and high flushing rates, accompanied by relatively low contaminant and turbidity levels, are positively correlated with the high productivity.

From an economic viewpoint these coastal wetlands exhibit high fish and wildlife values. Because these functions and values are linked to the ecology of Lake St. Clair, they cannot easily be replaced or mitigated. With regard to human uses, passive recreation and open space designation appear to be more suitable than intensive activities. Uses involving hydrologic modification of the wetlands and permanent intrusions often create large and irreparable disturbances. It is expected that urban development will result in the filling or destruction of most coastal wetlands along western Lake St. Clair, northward to St. John's Marsh. Moreover, south of Mitchell Bay, agricultural encroachment may isolate all but the cattail marsh fringe. It is unlikely that the Clinton River mouth and the St. John's Marsh wetlands will be restored. Nevertheless, because of the recognized value of the remaining wetlands, we believe that most of the extant wetlands will be preserved in their present state.

The future impacts on Lake St. Clair wetlands are dependent upon legislative efforts and public awareness in the Great Lakes basin of the value of the resource base. Legislatively, the State of Michigan has been a leader in environmental protection of wetlands. For example, the following laws have been enacted:

<u>The Great Lakes Submerged Lands Act</u> -- Public Act 247 of 1955, as amended, prohibits constructing or dredging any artificial body of water that would ultimately connect with a Great Lake. This act also requires a permit from the Department of Natural Resources to fill any submerged lands in a Great Lake, including Lake St. Clair.

<u>The Shorelands Protection and Management Act</u> -- Public Act 245 of 1970, as amended, designates wetlands adjacent to a Great Lake or a connecting waterway such as the St. Clair River as environmental areas necessary to preserve fish and wildlife.

The Goemaere-Anderson Wetland Protection Act -- Public Act 203 of 1979 regulates wetlands through several important laws relating to shorelands and submerged lands.

In Ontario, wetlands are viewed as recreational land and are thus taxed as such. Taxation of agricultural land is less than recreational land. This unbalanced tax structure is an incentive to drain and dike wetlands in Ontario for agricultural purposes (G. B. McCullough, Canadian Wildlife Service; pers. comm.). Several wetlands north of the Thames River including hunting clubs lands have succumbed to the tax pressure and have been converted to agriculture.

It is most fortunate that large tracts of wetlands are owned by State or Federal agencies. Assuming that the governing agencies will preserve the resource, most of the Michigan portion of the St. Clair Delta will be protected from future development. In Ontario the Walpole Island Indian Reserve encompasses Seaway, Squirrel, Walpole and St. Anne Islands. The preservation prospects for this portion of the modern delta are reasonably bright.

The Michigan DNR has made a concerted and sustained effort to inform the public of the value, in terms of economic returns, of the State's wetlands. Through funded wetland research and literature, the assets of the wetland resources have been disseminated to the public.

In spite of legislative and public awareness efforts, there are still areas of concern. Both in Michigan and Ontario, bulkheading and filling for small residential development continue, particularly along the natural levees of South and Middle channels and the shelf areas. In spite of Michigan PA 247 and PA 245, diked disposal sites for polluted dredge spoil were constructed on the premodern delta of Dickinson Island in the mid-1970s. Although Michigan's efforts to preserve these coastal wetlands have been positive, alteration is continuing.

Dickinson Island provides an example of a coastal wetland which has not been significantly altered. The hydrological connectivity is good and the wetland diversity is well displayed. Conversely, many wetlands, especially in Ontario, have been diked and are less diverse since there is a dominance of cattail. It is often pointed out that Lake St. Clair is located in waterfowl flyways and is an important staging area for migration, a fact which justifies diking to some degree. However, as noted earlier, the economic value of sport fishing greatly exceeds waterfowl hunting and trapping combined. More specifically, the economic value of Lake St. Clair to sport fishing, including coldwater species, has a value of $5,641 per wetland hectare/year (Jaworski and Raphael 1978). To detach the sportfish habitat from the wetland ecosystem may well decrease wetland diversity and the economic value of the St. Clair Delta. Also the cost for dike construction and maintenance in view of decreasing diversity ought to be considered.

Coastal erosion is modest on the shorelines of the lake, and seiches and flooding are beneficial flushing agents and nutrient transport mechanisms to the open-water bodies of the bays and lake. Diking preserves a rather monotypic wetland, prohibits adequate hydrologic connectivity, and decreases wetland utility in a low wave energy environment. Diking--to preserve wetlands in higher wave energy environments or in coastal areas dominated by fine clastic sediments or where geological subsidence is occurring such as western Lake Erie--appears to have some justification and trade-off value. In Lake St. Clair the environmental (i.e., hydrological and geological) considerations ought to encourage wetlands preservation to be directed to optimum hydrologic connectivity between the resource and the open lake.

In November 1984, a "Great Lakes Coastal Wetlands Colloquium," co-sponsored by the Sea Grant Program and Environment Canada, was held on the campus of Michigan State University to explore natural and manipulated water levels in Great Lakes wetlands. Besides providing a forum for the exchange of current research information, the meeting resulted in the establishment of a network of wetland

ecologists and managers in the Great Lakes region and plans for the publication of a quarterly newsletter for such workers. Although the conference pointed out the need for more research directed toward understanding processes and wildlife utilization of the coastal marshes, an equally important consideration was the alarming loss of wetlands. If there was a central theme of the conference, it would have to be that the conferees were in agreement that the existing coastal wetlands must be vigorously preserved if these valuable habitats are to survive intense development pressures.

Gary B. McCullough of the Canadian Wildlife Service documented the extensive conversion of coastal marshes to agricultural lands along the Ontario shore of Lake St. Clair which has taken place in the past several decades. He estimated that 36% of the original wetlands have been lost. Much of the remaining wetland area south of the St. Clair Delta is protected by dikes and water level control structures. John Ball of the University of Guelph reported that in these marshes, such as the ones owned by Ducks Unlimited or within the St. Clair National Wildlife Area (Canada), waterfowl utilization can be enhanced by clearing open areas in the cattail marshes (Ball 1984). To attract migrating ducks the optimal size of the opening appears to be approximately 50 m. The colloquium concluded with the remarks of Harold H. Prince, underscoring the "signature" which coastal wetlands impart to the fish and wildlife resources of the region. He pointed out that the significance of these marshes can be appreciated by recognizing: 1) that so many animals have embraced wetland habitats as part of their life strategy and 2) that wetlands are indicators of littoral and upland environmental quality. The ideas put forth at this conference are likely to shape the direction of wetlands research in the Great Lakes region for the next decade.

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APPENDIX A

DIMENSIONS OF LAKE ST. CLAIR AND ST. CLAIR RIVER WETLANDS BY UNITED STATES AND CANADA QUADRANGLE MAPS[a]

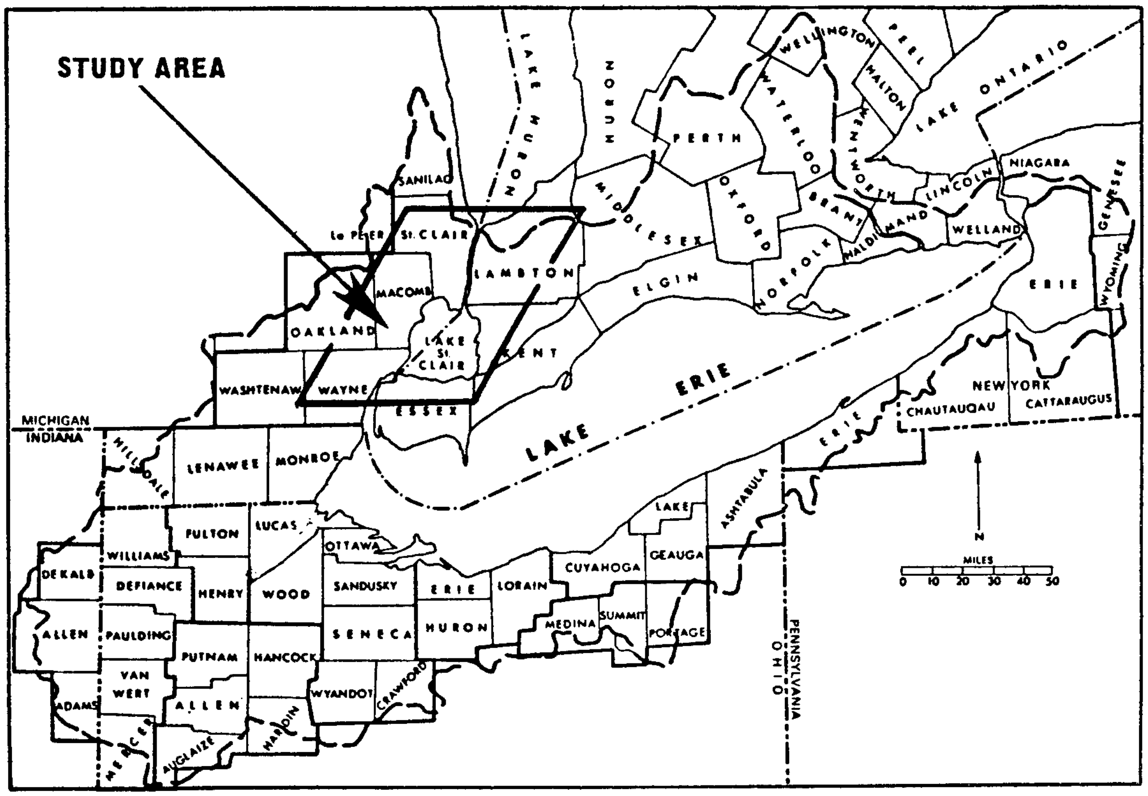
Jurisdiction and quadrangle map	Coastal length of wetlands (km)	Area of wetlands (km^2)
MICHIGAN:		
Wayne County		
Belle Isle Quadrangle	3.0	0.40
Detroit Quadrangle	1.0	0.30
Subtotal	4.0	0.70
Macomb County		
Grosse Point Quadrangle	0.7	0.25
Mt. Clemens Quadrangle	5.6	9.51
New Haven Quadrangle	0.3	0.47
Subtotal	6.6	10.23
St. Clair County		
Algonac Quadrangle	17.1	17.43
Marine City Quadrangle	7.2	12.38
New Baltimore Quadrangle	14.4	38.73
Port Huron Quadrangle	0.3	0.20
St. Clair Quadrangle	0.1	0.77
St. Clair Flats Quadrangle	36.1	71.14
Subtotal	75.2	140.65
MICHIGAN TOTAL	85.8	151.58
ONTARIO:		
Essex County		
Belle River Quadrangle	1.0	0.13
Riverside Quadrangle	1.0	0.16
Stoney Point Quadrangle	7.4	2.50
Tilbury Quadrangle	2.1	4.02
Subtotal	11.5	6.81

APPENDIX A (CONTINUED)

Jurisdiction and quadrangle map	Coastal length of wetlands (km)	Area of wetlands (km^2)
Kent County		
Mitchell Bay Quadrangle	19.8	40.63
Tilbury Quadrangle	6.7	21.19
Wallaceburg Quadrangle	--	1.01
Subtotal	26.5	62.83
Lambton County		
Courtright Quadrangle	1.2	0.18
Johnston Channel Quadrangle	17.6	25.73
Mitchell Bay Quadrangle	3.6	17.07
Sarnia Quadrangle	0.8	0.40
Seaway Island Quadrangle	11.9	24.19
Sombra Quadrangle	3.4	0.82
Wallaceburg Quadrangle	5.1	22.50
Walpole Island Quadrangle	20.8	70.80
Subtotal	64.4	161.69
ONTARIO TOTAL	102.4	231.33
LAKE ST. CLAIR/ST. CLAIR RIVER TOTAL	188.2	382.91

[a]Data sources: United States Geological Survey, Dept. Interior, 7.5-minute Quadrangle Maps (1:24,000 scale); Canada Department of Energy, Mines, and Resources, 7.5-minute Quadrangle Maps (1:25,000 scale).

APPENDIX A (CONCLUDED)



APPENDIX B

MEAN MONTHLY ST. CLAIR RIVER FLOWS, 1900 TO 1980[a]

Flow in cubic meters per second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WGTD MEAN
1900	4190	3960	3960	5130	5240	5300	5440	5470	5550	5580	5640	5440	5077
1901	4700	3570	4360	3600	5490	5720	5780	5780	5660	5610	5550	5300	5105
1902	4130	4300	5180	5270	5320	5440	5410	5490	5380	5270	5300	5150	5141
1903	3990	3880	4900	5240	5240	5320	5440	5440	5490	5610	5440	5150	5102
1904	4330	4190	4360	5300	5520	5720	5780	5800	5780	5800	5690	5350	5304
1905	3570	3940	4560	5550	5660	5780	5830	5860	5860	5830	5720	5610	5321
1906	5470	4250	4810	5660	5780	5780	5830	5800	5720	5610	5550	5150	5458
1907	4420	4110	4900	5580	5640	5720	5830	5800	5830	5720	5610	5490	5395
1908	3960	3740	4730	5440	5610	5780	5390	5830	5690	5550	5440	5380	5258
1909	4810	3450	4360	5210	5380	5520	5580	5520	5490	5380	5210	5040	5090
1910	3910	3960	5040	5150	5270	5350	5300	5270	5240	5240	5150	4790	4978
1911	3820	3680	4810	4900	5100	5180	5210	5210	5100	5100	5040	4960	4850
1912	3850	3990	4420	4760	5010	5320	5320	5410	5440	5490	5490	5490	5002
1913	5210	4130	4670	5210	5440	5640	5720	5660	5550	5610	5550	5410	5325
1914	4360	4360	4560	5210	5270	5380	5410	5410	5440	5380	5380	4980	5098
1915	3710	4220	4840	5130	5100	5150	5150	5150	5150	5150	5150	5010	4912
1916	4640	4020	4110	5100	5320	5490	5660	5660	5640	5550	5610	5490	5194
1917	4530	4530	5440	5490	5610	5720	5920	5970	5830	5750	5720	4760	5444
1918	4080	4560	4980	4560	6060	6170	6090	6000	5920	5750	5780	5660	5473
1919	5380	5240	5300	5380	5610	5580	5660	5610	5520	5440	5410	5410	5463
1920	3480	3740	4730	5470	5580	5640	5720	5660	5690	5610	5440	5320	5177
1921	5240	3850	5070	5130	5380	5380	5350	5320	5210	5240	5040	5100	5119
1922	4080	3790	4640	5130	5320	5470	5470	5440	5350	5270	5180	5010	5020
1923	3790	3850	4250	4840	4960	5210	5180	5180	5150	5100	4980	4790	4778
1924	4250	3450	4360	4590	4790	5010	5040	5100	5100	4960	4790	4250	4645
1925	3770	3680	4190	4590	4700	4670	4700	4640	4530	4530	4420	4450	4410
1926	3110	3260	3600	4330	4560	4700	4700	4670	4590	4530	4470	4500	4257
1927	3200	3480	4130	4700	4870	5040	5040	5040	4930	4980	4870	4810	4597
1928	4020	3280	3880	5100	5300	5320	5380	5490	5550	5610	5690	5610	5024
1929	4790	4640	5410	5720	6060	6170	6230	6230	6120	5890	5890	5040	5688
1930	4530	4700	5440	5380	5490	5610	5720	5720	5610	5440	5270	5100	5338
1931	4160	3140	3510	4960	4980	4930	4960	4810	4700	4700	4760	4640	4529
1932	4450	4470	3790	4590	4530	4620	4700	4670	4560	4500	4420	4110	4450
1933	4220	3280	4110	4280	4390	4590	4590	4590	4470	4420	4390	4130	4295
1934	3060	3430	3740	4360	4420	4470	4500	4530	4500	4500	4390	4450	4200
1935	3650	4220	4250	4530	4560	4640	4730	4730	4640	4620	4590	3990	4429
1936	3820	3770	4250	4700	4810	4900	4870	4790	4840	4870	4760	4560	4580

APPENDIX B (CONCLUDED)

Flow in cubic meters per second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WGTD MEAN
1937	4500	3450	4560	4450	4620	4670	4640	4640	4700	4670	4670	4360	4501
1938	3600	4110	3740	4760	4930	5040	5150	5210	5180	5150	5100	4980	4748
1939	4470	3960	4080	4840	5100	5210	5320	5380	5380	5320	5240	5100	4956
1940	3570	4050	4300	4760	4840	4930	4980	4980	5070	4930	4930	4840	4687
1941	3960	3680	4390	4760	5010	4980	4980	4900	4930	5040	5130	5100	4745
1942	4160	3000	4590	5130	5240	5350	5380	5350	5320	5270	5210	5010	4930
1943	3960	4190	4640	5270	5210	5550	5720	5890	5890	5800	5780	5610	5298
1944	4220	4640	4760	5440	5490	5550	5610	5610	5610	5610	5490	5380	5285
1945	4250	4590	5130	5180	5270	5490	5640	5610	5550	5490	5520	5300	5255
1946	4670	4530	5520	5690	5660	5610	5640	5550	5490	5380	5320	5240	5363
1947	4280	4190	5010	4930	5210	5380	5610	5610	5610	5610	5610	5440	5214
1948	4900	4700	4980	5380	5490	5490	5520	5520	5380	5210	5100	5040	5227
1949	4840	4590	4330	4930	5040	5040	5150	5130	5040	4870	4810	4620	4867
1950	4330	3790	4020	4560	4810	4980	5150	5300	5270	5270	5270	5040	4822
1951	4390	4420	5100	5300	5610	5690	5890	5970	5950	6060	6060	5950	5539
1952	5750	5720	5750	6090	6230	6340	6340	6460	6400	6290	6090	6030	6125
1953	5920	5690	5780	5830	6060	6120	6230	6260	6170	6060	5950	5780	5990
1954	4790	4450	5580	5550	5780	5890	6060	6060	5970	6030	6060	5950	5689
1955	5520	5240	5580	5690	5830	5830	5830	5720	5490	5380	5320	5180	5553
1956	4080	4020	4700	5130	5100	5350	5380	5380	5320	5240	5210	5100	5003
1957	4130	4420	4900	4870	4930	5040	5150	5100	5100	4980	4980	4900	4877
1958	3990	3740	4640	4640	4980	4870	4870	4840	4790	4700	4670	4360	4596
1959	3340	3620	4280	4390	4700	4840	4870	4900	4930	4900	4960	4900	4558
1960	4640	4190	4670	4900	5380	5550	5780	5800	5780	5720	5610	5300	5281
1961	4930	5100	5180	5150	5150	5210	5300	5300	5300	5350	5320	5150	5204
1962	4330	4160	4900	5130	5300	5320	5320	5240	5270	5100	4930	4640	4975
1963	4020	3740	4300	4590	4760	4840	4870	4900	4810	4760	4700	4420	4564
1964	3770	3600	4130	4160	4390	4420	4500	4530	4560	4560	4500	4360	4292
1965	3710	3770	4080	4390	4700	4810	4870	4930	4960	5100	5040	4930	4612
1966	4840	4590	4810	5010	5150	5150	5210	5130	5100	5010	4870	4840	4978
1967	4730	4420	4730	4980	5180	5270	5440	5440	5380	5210	5320	5100	5104
1968	4620	4640	4980	5040	5180	5270	5440	5550	5580	5610	5580	5350	5238
1969	4640	5130	5270	5380	5550	5720	5890	6000	5950	5860	5830	5520	5563
1970	4250	4700	5410	5440	5640	5780	5830	5860	5860	5780	5780	5660	5503
1971	5210	4980	5550	5800	5970	6060	6170	6170	6090	6000	5950	5750	5813
1972	5610	5320	5440	5490	5890	6060	6060	6170	6290	6260	6120	5950	5890
1973	5860	5490	5690	6060	6260	6370	6460	6510	6460	6370	6290	6060	6161
1974	5660	5720	5830	5950	6200	6430	6570	6480	6400	6230	6170	5950	6135
1975	5690	5550	5440	5830	6120	6230	6310	6230	6170	6000	5860	5800	5938
1976	4729	4984	5494	6003	6230	6286	6315	6230	6060	5890	5692	5154	5757
1977	4191	4672	5154	5323	5351	5409	5409	5437	5324	5324	5437	5154	5184
1978	4814	4701	4899	5069	5267	5437	5607	5635	5663	5777	5663	5437	5335
1979	4531	4757	5267	5550	5890	6003	6088	6145	6088	5918	5833	5833	5664
1980	5635	5493	5437	5607	5777	5862	5918	5890	5890	5918	5748	5409	5716

[a]Data source: U.S. Army Corps of Engineers.

APPENDIX C

ALGAE OCCURRING IN COASTAL WETLANDS AND NEARSHORE WATERS OF LAKE ST. CLAIR[a]

Taxa	Form and habitat
Phylum Cyanophyta (blue-greens)	
Class Myxophyceae	
Order Chroococcales	
Family Chroococcaceae	
Aphanocapsa delicatissima	Colonial; planktonic
Aphanocapsa elachista	Colonial; planktonic
Aphanocapsa grevillei	Colonial; planktonic
Coelosphaerium pallidum	Colonial; planktonic
Gomphosphaeria aponina	Colonial; planktonic
Gomphosphaeria lacustris	Colonial; planktonic
Merismopedia convoluta	Colonial; planktonic
Merismopedia punctata	Colonial; planktonic
Microcystis aeruginosa	Colonial; planktonic
Order Hormogonales	
Family Oscillatoriaceae	
Oscillatoria sp.	Filamentous; planktonic
Tolypothrix linata	Filamentous; sessile & planktonic mats
Family Nostocaceae	
Anabaena sp.	Filamentous; planktonic
Family Rivulariaceae	
Gloeotrichia pisum	Colonial; among marsh plants, sessile & planktonic
Phylum Euglenophyta (euglenoids)	
Class Euglenophyceae	
Order Euglenales	
Family Euglenaceae	
Euglena pisciformis	Solitary; planktonic
Euglena spirogyra	Solitary; planktonic
Phacus longicauda	Solitary; planktonic
Trachelomonas sp.	Solitary; planktonic

APPENDIX C (CONTINUED)

Taxa	Form and habitat
Phylum Chrysophyta (golden-browns)	
Class Xanthophyceae (yellow-greens)	
Order Heterococcales	
Family Chlorotheciaceae	
Ophiocytium cochleare	Solitary; among marsh plants & planktonic
Order Heterotrichales	
Family Tribonemataceae	
Tribonema sp.	Filamentous; planktonic
Order Heterosiphonales	
Family Vaucheriaceae	
Vaucheria geminata	Filamentous; among marsh plants
Vaucheria tuberosa	Filamentous; among marsh plants
Class Chrysophyceas (golden algae)	
Order Chrysomonadales	
Family Ochromonadaceae	
Dinobryon borgei	Colonial; planktonic
Dinobryon sertularia	Colonial; planktonic
Dinobryon sociale	Colonial; planktonic
Class Bacillariophycea (diatoms)	
Order Centrales (centric diatoms)	
Family Coscinodiscaceae	
Stephanodiscus sp.	Solitary; planktonic
Order Pennales (pennate diatoms)	
Family Fragilariaceae	
Tabellaria fenestrata	Solitary; planktonic
Tabellaria flocculosa	Solitary; planktonic
Asterionella formosa	Solitary; planktonic
Fragilaria bicapitata	Solitary; planktonic
Fragilaria crotonesis	Solitary; planktonic
Synedra attinis	Solitary; planktonic
Family Achnanthaceae	
Achnanthes sp.	Solitary; planktonic
Family Naviculaceae	
Gyrosigma sp.	Solitary; planktonic
Navicula viridis	Solitary; planktonic, & attached to aquatic plants
Pleurosigma sp.	Solitary; planktonic

APPENDIX C (CONTINUED)

Taxa	Form and habitat
Family Gomphonemaceae	
Gomphonema geminatum	Solitary; planktonic
Family Cymbellaceae	
Cymbella gastoides	Solitary; planktonic
Family Nitzschiaceae	
Nitzschia sigmoidea	Solitary; planktonic
Phylum Pyrrhophyta (fire algae)	
Class Dinaphyceae (dinoflagellates)	
Order Peridiniales	
Family Peridiniaceae	
Peridinium tabulatum	Solitary; planktonic
Family Ceratiaceae	
Ceratium hirundinella	Solitary; planktonic
Phylum Chlorophyta (greens)	
Class Chlorophyceae	
Order Volvocales	
Family Chlamydomonadaceae	
Chlamydomonas sp.	Solitary; planktonic
Family Volvocaceae	
Eudorina elegans	Colonial; planktonic
Pandorina morum	Colonial; planktonic
Pleodorina illinoisensis	Colonial; planktonic
Order Tetrasporales	
Family Palmellaceae	
Asterococcus limneticus	Colonial; planktonic
Family Tetrasporaceae	
Tetraspora lacustris	Colonial; planktonic
Order Microsporales	
Family Microsporaceae	
Microspora sp.	Filamentous; planktonic
Order Chaetophorales	
Family Chaetophoraceae	
Chaetophora cornu-damae	Filamentous; attached to aquatic plants & debris

Taxa	Form and habitat
Family Protococcaceae	
Protococcus viridis	Solitary; planktonic attached to organic debris
Family Coleochaetaceae	
Coleochaete scutata	Filamentous; attached to organic debris
Order Cladophorales	
Family Cladophoraceae	
Cladophora sp.	Filamentous; attached to aquatic plants
Pithophora sp.	Filamentous; planktonic
Order Oedogoniales	
Family Oedogoniaceae	
Bulbochaete sp.	Filamentous; attached to aquatic plants
Order Chlorococcales	
Family Hydrodictyaceae	
Pediastrum biradiatum	Colonial; planktonic
Pediastrum boryanum	Colonial; planktonic & among marsh plants
Pediastrum duplex	Colonial; planktonic & among marsh plants
Pediastrum glanduliferum	Colonial; planktonic
Pediastrum integrum	Colonial; planktonic
Pediastrum kawraiskyi	Colonial; planktonic
Pediastrum obtusum	Colonial; planktonic
Pediastrum sculptatum	Colonial; planktonic
Pediastrum simplex	Colonial; planktonic
Pediastrum tetras	Colonial; planktonic
Sorastrum spinulosum	Colonial; planktonic & among marsh plants
Family Coelastraceae	
Coelastrum cambricum	Colonial; planktonic
Coelastrum microporum	Colonial; among marsh plants
Coelastrum sphaericum	Colonial; planktonic
Family Botryococcaceae	
Botryococcus braunii	Colonial; planktonic

Taxa	Form and habitat
Family Oocystaceae	
Ankistrodesmus falcatus	Solitary; planktonic
Chlorella sp.	Solitary; planktonic
Dictyosphaerium pulchellum	Colonial; planktonic
Nephrocytium agardhianum	Colonial; among marsh plants
Schroederia sp.	Solitary; planktonic
Selenastrum westii	Colonial; planktonic
Tetraedron minimum	Solitary; among marsh plants
Family Scenedesmaceae	
Actinastrum gracilimum	Colonial; planktonic
Actinastrum hantzschii	Colonial; planktonic
Crucigenia quadrata	Colonial; planktonic
Scenedesmus bijuga	Colonial; among marsh plants
Scenedesmus cordatus	Colonial; among marsh plants
Scenedesmus opliensis	Colonial; planktonic
Scenedesmus quadricauda	Colonial; planktonic
Order Zygnematales	
Family Zygnemataceae	
Mougeotia sp.	Filamentous; planktonic
Spirogyra nitida	Filamentous; marsh pools
Zygnema sp.	Filamentous; plantonic
Family Desmidiaceae (desmids)	
Closterium acerosum	Solitary; among marsh plants
Closterium dianae	Solitary; among marsh plants
Closterium ehrenbergii	Solitary; among marsh plants
Closterium gracile	Solitary; among marsh plants
Closterium juncidum	Solitary; among marsh plants
Closterium leibleinii	Solitary; among marsh plants
Closterium lineatum	Solitary; among marsh plants
Closterium moniliferum	Solitary; attached to debris
Closterium rostratum	Solitary; among marsh plants
Closterium venus	Solitary; among marsh plants
Cosmarium botrytis	Solitary; among marsh plants
Cosmarium broomei	Solitary; among marsh plants
Cosmarium contractum	Solitary; among marsh plants
Cosmarium granatum	Solitary; among marsh plants
Cosmarium impressulum	Solitary; among marsh plants
Cosmarium intermedium	Solitary; planktonic & sessile
Cosmarium latium	Solitary; among marsh plants
Cosmarium margaritiferum	Solitary; among marsh plants
Cosmarium meneghinii	Solitary; among marsh plants
Cosmarium nitidulum	Solitary; among marsh plants
Cosamrium ornatum	Solitary; among marsh plants

APPENDIX C (CONCLUDED)

Taxa	Form and habitat
Cosmarium portianum	Solitary; among marsh plants
Cosmarium schliephacheanum	Solitary; among marsh plants
Cosmarium subcrenatum	Solitary; among marsh plants
Cosmarium sulcatum	Solitary; among marsh plants
Cosmarium tetraophthalmum	Solitary; among marsh plants
Desmidium aptognium	Filamentous; among marsh plants
Desmidium baileyi	Filamentous; among marsh plants
Desmidium swartzii	Filamentous; among marsh plants
Disphinctium connatum	Solitary; among marsh plants
Euastrum binale	Solitary; among marsh plants
Euastrum elegans	Solitary; among marsh plants
Euastrum verrucosum	Solitary; among marsh plants
Gonatozygon ralfsii	Filamentous; among marsh plants
Hyalotheca dissiliens	Filamentous; among marsh plants
Micrasterias crux-melitensis	Solitary; among marsh plants
Micrasterias fimbriata	Solitary; among marsh plants
Micrasterias rotata	Solitary; among marsh plants
Micrasterias truncata	Solitary; among marsh plants
Onychonema leve	Solitary; among marsh plants
Penium margaritaceum	Filamentous; among marsh plants
Pleurotaenium trabecula	Solitary; among marsh plants
Sphaerozosma wallichii	Solitary; among marsh plants
Staurastrum alternans	Solitary; among marsh plants
Staurastrum arctiscon	Solitary; planktonic & among marsh plants
Staurastrum aspinosum	Solitary; planktonic & among marsh plants
Staurastrum avicula	Solitary; among marsh plants
Staurastrum brevispina	Solitary; planktonic
Staurastrum crenulatum	Solitary; among marsh plants
Staurastrum dejectum	Solitary; planktonic & among marsh plants
Staurastrum dickiei	Solitary; among marsh plants
Staurastrum echinatum	Solitary; among marsh plants
Staurastrum furcigerum	Solitary; among marsh plants
Staurastrum gracile	Solitary; among marsh plants
Staurastrum incisum	Solitary; among marsh plants
Staurastrum margaritaceum	Solitary; among marsh plants
Staurastrum muticium	Solitary; among marsh plants
Staurastrum polymorphum	Solitary; among marsh plants
Staurastrum teliferum	Solitary; among marsh plants

[a]Data sources: Pieters (1893), Winner et al. (1970), Taft and Taft (1971), Michigan Water Resources Commission (1975).

APPENDIX D

ZOOPLANKTON OCCURRING IN THE COASTAL WETLANDS AND NEARSHORE WATERS OF LAKE ST. CLAIR[a]

Species	Abundance status
Phylum Protozoa (protozoans)	
Class Sarcodina	
Order Amoebida	
Family Amoebida	
Amoeba proteus	Uncommon
Family Arcellidae	
Arcella dentata	Rare
Arcella vulgaris	Common
Centropyxis aculeata	Common
Difflugia corona	Common
Difflugia globulosa	Abundant
Difflugia pyriformis	Common
Order Heliozoa (sun animalcules)	
Family Aphrothoracidae	
Actinophrys sol	Uncommon
Class Ciliophora (ciliates)	
Order Holotrichida	
Family Trachelinidae	
Amphileptus gigas	Common
Family Chlamydodontidae	
Nassula ornata	Common
Family Stentoridae	
Stentor sp.	Uncommon
Order Oligotrichida	
Family Tintinnidae	
Codonella cratera	Common

APPENDIX D (CONTINUED)

Species	Abundance status
Order Peritrichida	
Family Vorticellidae	
Epistyllis plicatilis	Occasional
Pyxicola constricta	Common
Vaginicola gigantea	Rare
Vorticella campanula	Uncommon
Family Ophrydiidae	
Ophrydium versatile	Common
Phylum Rotatoria (rotifers)	
Class Monogononata (single ovary rotifers)	
Order Flosculariacea	
Family Conochilidae	
Conochilus unicornis	Abundant
Family Testudinellidae	
Filinia longiseta	Common
Filinia terminalis	Rare
Order Collothecacea	
Family Collothecidae	
Collotheca mutabilis	Common
Order Ploimacea	
Family Notommatidae	
Cephalodella gibba	Rare
Monommata sp.	Rare
Family Synchaetidae	
Polyarthra euryptera	Rare
Polyarthra major	Occasional
Polyarthra remata	Occasional
Polyarthra vulgaris	Abundant
Synchaeta stylata	Abundant
Synchaeta kitina	Rare
Family Ploesomatidae	
Ploesoma hudsonii	Rare
Ploesoma lenticulare	Occasional
Ploesoma truncatum	Common
Family Gastropodidae	
Chromogaster ovalis	Occasional
Gastropus stylifer	Uncommon

Species	Abundance status
Family Trichoceridae	
Trichocerca capucina	Rare
Trichocerca cylindrica	Occasional
Trichocerca lata	Rare
Trichocerca longiseta	Rare
Trichocerca mucosa	Rare
Trichocerca multicrinis	Occasional
Trichocerca porcellus	Rare
Trichocerca similis	Rare
Trichocerca stylata	Rare
Family Asplanchnidae	
Asplanchna herrickii	Rare
Asplanchna priodonta	Common
Family Brachionidae	
Anuraeopsis fissa	Rare
Brachionus angularis	Abundant
Brachionus bidentatua	Rare
Brachionus budapestinensis	Common
Brachionus calyciflorus	Occasional
Brachionus caudatus	Occasional
Brachionus quadridentatus	Rare
Brachionus rubens	Rare
Brachionus urceolaris	Rare
Euchlanis dilatata	Rare
Euchlanis triquetra	Rare
Kellicottia longispina	Abundant
Keratella cochlearis	Abundant
Keratella crassa	Common
Keratella quadrata	Common
Keratella valga	Rare
Notholca acuminata	Rare
Notholca foliacea	Rare
Notholca laurentiae	Rare
Notholca squamula	Rare
Platyias platulus	Rare
Trichotria tetractis	Rare
Colurella obtusa	Rare
Lepadella patella	Rare
Lecane spp.	Rare
Lecane luna	Rare
Monostyla bulla	Rare
Monostyla lunaris	Rare
Monostyla quadridentata	Rare

Species	Abundance status
Family Tylotrochidae	
Tylotrocha monopus	Rare
Phylum Arthropoda (joint-legged animals)	
Class Crustacea	
Order Cladocera (water fleas)	
Family Daphnidae	
Ceriodaphnia lacustris	Uncommon
Ceriodaphnia quadrangula	Rare
Daphnia ambigua	Rare
Daphnia galeata mendotae	Common
Daphnia longispina	Common
Daphnia parvula	Occasional
Daphnia pulex	Uncommon
Daphnia retrocurva	Common
Family Leptodoridae	
Leptodora kindtii	Occasional
Family Sididae	
Diaphanosoma brachyurum	Uncommon
Diaphanosome leuchtenbergianum	Uncommon
Sida crystallina	Rare
Family Holopedidae	
Holopedium gibberum	Occasional
Family Bosminidae	
Bosmina longirostris	Abundant
Eubosmina coregoni	Abundant
Family Chydoridae	
Alona costata	Uncommon
Alona intermedia	Rare
Alona quadrangularis	Rare
Alonella spp.	Rare
Anchistropus minor	Rare
Camptocercus rectirostris	Rare
Chydorus latus	Rare
Chydorus sphaericus	Occasional
Eurycercus lamellatus	Rare
Pleuroxus denticulatus	Rare
Family Macrothricidae	
Ilyocryptus spinifer	Rare

APPENDIX D (CONCLUDED)

Species	Abundance status
Order Copepoda	
Suborder Calanoida (calanoid copepods)	
Family Centropagidae	
Limnocalanus macrurus	Rare
Family Diaptomidae	
Diaptomlus ashlandi	Abundant
Diaptomus minutus	Common
Diaptomus oregonensis	Common
Diaptomus sicilis	Common
Diaptomus siciloides	Occasional
Family Temoridae	
Epischura lacustris	Uncommon
Eurytemora affinis	Uncommon
Suborder Cyclopoida (cyclopoid copepods)	
Family Cyclopoida	
Cyclops bicuspidatus thomasi	Abundant
Cyclops vernalis	Common
Eucyclops agilis	Rare
Mesocyclops edax	Common
Tropocyclops prasinus mexicanus	Occasional
Suborder Harpacticoida (harpacticoid copepods)	
Family Harpacticidae	
Canthocamptus robertcokeri	Rare

[a]Data sources: Birge (1894), Jennings (1894), Reighard (1894), Marsh (1895), Winner et al. (1970), Bricker et al. (1976).

APPENDIX E

VASCULAR AQUATIC PLANTS OCCURRING IN LAKE ST. CLAIR WETLANDS[a]

Ecological niche and species	Abundance status[b]
EMERGENT AND SHORE PLANTS	
Class Angiospermae (flowering plants)	
Subclass Monocotyledonae (monocots)	
Order Pandanales	
Family Typhaceae (cattails)	
Typha angustifolia (narrow-leaved cattail)	C
Typha latifolia (broad-leaved cattail)	C
Typha x *glauca* (hybrid cattail)	A
Family Sparganium (bur reeds)	
Sparganium eurycarpum (giant bur reed)	A
Order Alismales	
Family Alismataceae (water plantains)	
Alisma plantago-aquatica (water plantain)	C
Sagittaria latifolia (common arrowhead)	C
Sagittaria ridgia (rigid arrowhead)	U
Family Butomaceae (flowering rushes)	
Butomus umbellatus (flowering rush)	U
Order Graminales	
Family Gramineae (grasses)	
Calamagrostis canadensis (bluejoint grass)	A
Glyceria canadensis (rattlesnake grass)	O
Glyceria striata (manna grass)	U
Leersia oryzoides (rice cut grass)	U
Panicum leibergii (panic grass)	O
Phalaris arundinacea (reed-canary grass)	C
Phragmites australis (=*communis*) (reed grass)	O
Poa palustris (fowl meadow grass)	O
Spartina pectinata (slough grass)	O
Triplasis purpurea (sand grass)	R
Zizania aquatica (wild rice)	R

Ecological niche and species	Abundance status
Family Cyperaceae (sedges)	
Carex comosa (bristly sedge)	C
Carex frankii (Frank's sedge)	O
Carex lacustris (lake sedge)	O
Carex lanuginosa (tussock sedge)	O
Carex lasiocarpa (tussock sedge)	O
Carex sartwellii (tussock sedge)	O
Carex stipata (awl-fruited sedge)	O
Carex stricta (tussock sedge)	O
Cyperus erythrorhizos (redrooted cyperus)	O
Cyperus ferruginescens (rusty cyperus)	O
Eleocharis erythropoda (redfooted spike-rush)	A
Eleocharis obtusa (blunt spike-rush)	C
Eleocharis palustris (creeping spike-rush)	A
Fimbristylis puberula (marsh sedge)	O
Scirpus acutus (hard-stem bulrush)	C
Scirpus pungens (=*americanus*) (American bulrush, three-square)	C
Scirpus atrovirens (dark green bulrush)	O
Scirpus fluviatilis (river bulrush)	O
Scirpus validus (great bulrush)	C
Order Xyridales	
Family Pontederiaceae (pickerel weeds)	
Heteranthera dubia (water stargrass, mud plantain)	C
Pontederia cordata (pickerel weed)	A
Order Liliales	
Family Juncaceae (rushes)	
Juncus effusus (soft rush)	C
Juncus nodosus (knotted rush)	O
Juncus torreyi (Torrey's rush)	O
Order Orchidales	
Family Orchidaceae (orchids)	
Habenaria leucophaea (prairie fringed orchid)	O
Subclass Dicotyledonae (dicots)	
Order Salicales	
Family Salicaceae (willows)	
Populus deltoides (eastern cottonwood)	O
Populus tremuloides (quaking aspen)	O
Salix sericea (silky willow)	O

APPENDIX E (CONTINUED)

Ecological niche and species	Abundance status
Order Myricales	
Family Juglandaceae (walnuts)	
Carya ovata (shagbark hickory)	O
Order Fagales	
Family Fagaceae (beeches)	
Quercus bicolor (swamp white oak)	O
Quercus macrocapra (burr oak)	O
Quercus palustris (pin oak)	O
Order Urticales	
Family Ulmaceae (elms)	
Ulmus americana (American elm)	O
Family Urticaceae (nettles)	
Urtica dioica (stinging nettle)	O
Order Polygonales	
Family Polygonaceae (smartweeds)	
Polygonum amphibium (water smartweed)	O
Polygonum coccineum (swamp persicaria)	U
Polygonum convolvulus (black bindweed)	O
Polygonum lapathifolium (nodding smartweed)	C
Polygonum pensylvanica (Pennsylvania smartweed, pinkweed)	O
Polygonum punctatum (water smartweed)	A
Rumex verticillatus (swamp dock)	O
Order Ranales	
Family Nymphaeaceae (water lilies)	
Nelumbo lutea (American water-lotus)	R
Nuphar advena (spatterdock, yellow water lily)	C
Order Papaverales	
Family Cruciferae (mustards)	
Cardamine pensylvania (bitter cress)	O
Rorippa palustris (marsh cress)	C
Order Rosales	
Family Crassulaceae (orpines)	
Penthorum sedoides (ditch stonecrop)	O
Family Rosaceae (roses)	
Potentilla anserina (silverweed)	O
Rosa palustris (swamp rose)	O

APPENDIX E (CONTINUED)

Ecological niche and species	Abundance status
Family Leguminosae (peas)	
Vicia angustifolia (vetch)	O
Order Sapindales	
Family Anacardiaceae (sumacs)	
Rhus typhina (staghorn sumac)	O
Family Aceraceae (maples)	
Acer saccharinum (silver maple)	O
Family Balsaminaceae (jewelweeds)	
Impatiens capensis (jewelweed)	O
Order Rhamnales	
Family Vitaceae (grapes)	
Vitis palmata (wild grape)	O
Order Malvales	
Family Malvaceae (mallows)	
Hibiscus palustris (=_mosheutos_) (swamp rosemallow)	R
Order Myrtales	
Family Lythaceae (loosestrifes)	
Decodon verticillatus (swamp loosestrife)	R
Family Onagraceae (evening-primroses)	
Ludwigia palustris (water primrose)	O
Order Umbelales	
Family Cornaceae (dogwoods)	
Cornus racemosa (gray dogwood)	
Cornus stolonifera (red osier dogwood)	O
Order Primulales	
Family Oleaceae (olives)	
Fraxinus pennsylvanica (red ash)	O
Family Asclepiadaceae (milkweeds)	
Asclepias incarnata (swamp milkweed)	C
Order Polemoniales	
Family Convolvulaceae (morning glories)	
Convolvulus sepium (morning glory)	O

Ecological niche and species	Abundance status
Family Boraginaceae (borages)	
Symphytum officinales (common comfrey)	O
Family Solanaceae (nightshades)	
Solanum dulcamara (nightshade)	O
Order Polemoniales	
Family Labiatae (mints)	
Lycopus americanus (water horehound)	O
Lycopus asper (western water horehound)	O
Lycopus europaeus (European horehound)	O
Scutellaria epilobiifolia (skullcap)	O
Scutellaria lateriflora (mad-dog skullcap)	O
Stachys palustris (woundwort)	O
Family Acanthaceae (acanthids)	
Justicia americana (water willow)	O
Order Rubiales	
Family Rubiaceae (madders)	
Cephalanthus occidentalis (buttonbush)	O
Order Campanulales	
Family Lobelliaceae (lobelias)	
Lobelia siphilitica (blue lobelia)	O
Order Asterales	
Family Compositae (composites)	
Bidens cernuus (nodding beggar tick)	U
Bidens commatus (purple-stemmed swamp beggar tick)	U
Cirsium hillii (Hill's thistle)	O
Eupatorium perfoliatum (bonset)	O
ATTACHED FLOATING-LEAVED PLANTS	
Class Angiospermae (flowering plants)	
Subclass Monocotyledonae (monocots)	
Order Najadales	
Family Potamogetonaceae (pondweeds)	
Potamogeton nodosus (knotty pondweed)	O
Subclass Dicotyledonae (dicots)	
Order Polygonales	
Family Polygonaceae (buckwheats)	
Polygonum amphibium (water smartweed)	A
Polygonum coccineum (swamp smartweed)	U

APPENDIX E (CONTINUED)

Ecological niche and species	Abundance status
Order Ranales	
Family Nymphaeaceae (water lilies)	
Nelumbo lutea (American lotus)	R
Nuphar advena (yellow water lily, spatterdock)	C
Nymphaea odorata (white water lily)	C
Nymphaea tuberosa (white water lily)	C
FLOATING PLANTS	
Class Angiospermae (flowering plants)	
Sublcass Monocotyledonae (monocots)	
Order Arales	
Family Lemnaceae (duckweeds)	
Lemna minor (small duckweed)	A
Spirodela polyrhiza (large duckweed)	C
Wolffia columbiana (watermeal)	O
Wolffia punctata (watermeal)	O
SUBMERSED PLANTS	
Class Angiospermae (flowering plants)	
Subclass Monocotyledonae (monocots)	
Order Najadales	
Family Najadaceae (bushy pondweeds)	
Najas marina (spiny naiad)	O
Najas minor (minor naiad)	O
Najas flexilis (naiad)	C
Family Potamogeton (pondweeds)	
Potamogeton crispus (curly pondweed)	C
Potamogeton foliosus (leafy pondweed)	O
Potamogeton pectinatus (sago pondweed)	O
Potamogeton pusillus (small, slender pondweed)	O
Potamogeton richardsonii (Richardson's pondweed)	U
Family Zannichelliaceae (horned pondweeds)	
Zannichellia palustris (horned pondweed)	O
Order Hydrocharitales	
Family Hydrocharitaceae (frogbits)	
Elodea canadensis (waterweed)	C
Vallisneria americana (eel grass, wild celery)	A

Ecological niche and species	Abundance status
Order Xyridales	
Family Pontederiaceae (pickerel weeds)	
Heteranthera dubia (mud plantain, water stargrass)	C
Subclass Dicotyledonae (dicots)	
Order Ranales	
Family Ranunculaceae (buttercups)	
Ranunculus longirostris (water crowfoot)	U
Order Myrtales	
Family Haloragidaceae (water milfoils)	
Myriophyllum alterniflorum (little water milfoil)	O
Myriophyllum heterophyllum (water milfoil)	O
Myriophyllum spicatum (water milfoil)	A
Family Onagraceae (evening primroses)	
Ludwigia palustris (water primrose)	C
SUSPENDED PLANTS	
Class Angiospermae (flowering plants)	
Subclass Monocotyledonae (monocots)	
Order Arales	
Family Lemnaceae (duckweeds)	
Lemna triscula (star duckweed)	O
Subclass Dicotyledonae (dicots)	
Order Ranales	
Family Ceratophyllaceae (hornworts)	
Ceratophyllaceae demersum (hornwort, coontail)	A
Order Polemoniales	
Family Lentibulariaceae (bladderworts)	
Utricularia vulgaris (bladderwort)	C

[a]Data sources: Stuckey (1968, 1972, 1975, 1979), Jaworski and Raphael (1978), Herdendorf et al. (1981c).

[b]Abundance status: A = abundant, c = common, O = occasional, R = rare, U = uncommon.

APPENDIX F

BENTHIC MACROINVERTEBRATES OF NEARSHORE LAKE ST. CLAIR AND CONNECTING WATERWAYS (EXCLUDING MOLLUSKS)[a]

Classification and species
Phylum Porifera (sponges)
Class Demospongiae (horny sponges)
Family Spongillidae (fresh-water sponges)
Spongilla spp.
Phylum Coelenterata (Class Cnidaria)
Class Hydrozoa (hydrozoans)
Family Hydridae
Hydra spp.
Phylum Platyhelminthes (flatworms)
Class Turbellaria (planarians)
Order Tricladida (triclads)
Family Planariidae (planarians)
Dugesia tigrina
Planaria sp.
Order Neorhabdocela
Family Provorticidae
Provortex sp.
Phylum Nematoda (roundworms)
Class Adenophorae
Family Tripylidae
Trilobus sp.
Phylum Annelida (segmented worms)
Class Polychaeta
Family Sabellidae (fan worms, feather-duster worms)
Manayunkia speciosa
Class Oligochaeta (aquatic earthworms)
Family Lumbriculidae
Sylodrilus heringianus

Classification and species
Family Tubificidae (sludge worms)
Aulodrilus americanus
Aulodrilus limnobius
Aulodrilus pigueti
Aulodrilus pluriseta
Branchiura sowerbyi
Ilyodrilus templetoni
Limnodrilus cervix
Limnodrilus claparedeianus
Limnodrilus hoffmeisteri
Limnodrilus maumeensis
Limnodrilus udekemianus
Peloscolex ferox
Peloscolex freyi
Peloscolex multisetosus
Potamothrix sp.
Family Naididae
Arcteonais lomondi
Chaetogaster diaphanus
Nais elinguis
Ophidonais serpentina
Piguetiella michiganensis
Pristina foreli
Pristina longiseta
Specaria josinae
Stylaria lacustris
Uncinais uncinata
Vejdovskyella intermedia
Wapsa mobilis
Family Glossoscolecidae
Sparganophilus tomensis
Class Hirudinea (leeches)
Family Glossiphoniidae
Glossiphonia complanata
Glossiphonia heteroclita
Helobdella stagnalis
Helobdella triserialis
Placodbella montifera
Order Pharyngobdellida
Family Erpobdellidae
Erpobdella sp.
Nephelopsis obscura

Classification and species

Phylum Arthropoda (joint-legged animals)
  Class Arachnida
    Order Acarina (mites and ticks)
      Superfamily Hydracarina (water mites)
        Family Limnesiidae
          Limnesia histrionica
          Limnesia maculata
          Limnesia paucispina

        Family Hygrobatidae
          Hygrobates sp.

        Family Pionidae
          Piona reighardi

  Class Crustacea
    Subclass Ostracoda (seed shrimps)
      Family Cypridae
        Cyprinotus spp.

    Subclass Malacostraca
      Order Isopoda (aquatic sowbugs)
        Family Asellidae
          Asellus communis
          Lirceus lineatus

      Order Amphipoda (sideswimmers, scuds)
        Family Gammaridae
          Crangonyx sp.
          Gammarus fasciatus

        Family Talitridae
          Hyalella azteca

        Family Haustoriidae
          Pontoporeia affinis

      Order Decapoda (crayfishes, shrimps)
        Suborder Reptantia (crayfishes)
          Family Cambaridae (crayfishes)
            Orconectes sp.

  Class Insecta (= Hexapoda) (insects)
    Order Ephemeroptera (mayflies)
      Family Baetiscidae
        Baetisca sp.

Classification and species
Family Ephemeridae (burrowing mayflies)
Ephemera sp.
Hexagenia limbata
Family Polymitarcidae
Ephoron album
Order Odonata (dragonflies and damselflies)
Suborder Anisoptera (dragonflies)
Family Gomphidae
Dromogomphus sp.
Suborder Zygoptera (damselflies)
Family Coenagrionidae (narrow-winged damselflies)
Enallagma sp.
Order Hemiptera (bugs)
Family Corixidae (water boatmen)
Sigara sp.
Order Trichoptera (caddisflies)
Family Hydroptilidae (micro-caddisflies)
Hydroptila sp.
Family Hydropsychidae (net-spinning caddisflies)
Cheumatopsyche sp.
Hydropsyche sp.
Family Polycentropodidae (tube-making caddisflies)
Neureclipsis sp.
Polycentropus sp.
Family Psychomyiidae (trumpet-net caddisflies)
Psychomyia sp.
Family Molannidae
Molanna sp.
Family Leptoceridae (long-horned caddisflies)
Ceraclea sp.
Mystacides sp.
Nectopsyche sp.
Oecetis sp.
Setodes sp.
Triaenodes sp.

Classification and species
Order Coleoptera (beetles)
Family Haliplidae (crawling water beetles)
Haliplus cribrarius
Family Elmidae (riffle beetles)
Dubiraphia sp.
Order Diptera (true flies)
Family Chaoboridae (phanton midges)
Chaoborus sp.
Family Culicidae (mosquitoes)
Culex sp.
Family Chironomidae (=Tendipedidae) (midges)
Chironomus spp.
Cryptochironomus spp.
Demicryptochironomus sp.
Micropsectra sp.
Paracladopelma sp.
Family Ceratopogonidae (biting midges, punkies)
Holoconops sp.

[a]Data sources: Wolcott (1903), Edmondson (1959), Hunt (1962), Hiltunen (1971, 1980), Modlin and Gannon (1973), Pennak (1978), Herdendorf et al. (1981c), Hiltunen and Manny (1982), Herdendorf and Herdendorf (1983).

APPENDIX G

TAXONOMIC LISTING OF FRESHWATER MOLLUSCA OF LAKE ST. CLAIR COASTAL MARSHES, NEARSHORE WATERS, AND TRIBUTARY MOUTHS[a]

Species
Class Gastropoda (snails)
Subclass Prosobranchia (gill-breathing snails)
Order Mesogastropoda
Superfamily Viviparidae (mystery snails)
Family Viviparidae (mystery snails)
Campeloma decisum (Say, 1816) brown mystery snail
Viviparus georgianus (Lea, 1834) banded mystery snail
Cipangopaludina chinensis (Gray, 1834) (= *V. japonicus*) oriental mystery snail or Japanese snail
Superfamily Valvatacea
Family Valvatidae (valve snails)
Valvata perdepressa Walker, 1906 flat valve snail
Valvata piscinalis (Muller, 1774) European valve snail
Valvata sincera sincera Say, 1824 ribbed valve snail
Valvata tricarinata (Say, 1817) three-keeled valve snail
Superfamily Rissoacea
Family Hydrobiidae (spire snails)
Cincinnatia cincinnatiensis (Anthony, 1840) campeloma spire snail
Probythinella lacustris (Baker, 1928) flat-ended spire snail
Marstonia decepta (Baker, 1928) Pilsbry's spire snail
Amnicola limosa (Say, 1817) ordinary spire snail
Amnicola walkeri Pilsbry, 1898 small spire snail
Somatogyrus subglobosus (Say, 1825) deep water spire snail
Family Truncatellidae (looping snails)
Pomatiopsis lapidaria (Say, 1817) river bank looping snail
Family Bithyniidae (faucet snails)
Bithynia tentaculata (Linnaeus, 1767) faucet snail
Superfamily Cerithiacea
Family Pleuroceridae (horn snails)
Pleurocera acuta Rafinesque, 1831 flat-sided horn snail
Goniobasis livescens (Menke, 1830) Great Lakes horn snail

Species
Subclass Pulmonata (lung-breathing snails)
Order Basommatophora
Superfamily Lymnaeacea
Family Lymnaeidea (pond snails)
Fossaria decampi (Streng, 1896) shouldered northern fossaria
Fossaria exigua (Lea, 1841) graceful fossaria
Fossaria modicella (Say, 1825) modest fossaria
Fossaria parva (Lea, 1841) amphibious fossaria
Bakerilymnaea dalli (Baker, 1907) small pond snail
Pseudosuccinea columella (Say, 1817) American ear snail
Acella haldemani (Binney, 1867) slender pond snail
Bulimnea megasoma (Say, 1824) showy pond snail
Lymnaea stagnalis jugularis (Say, 1817) great pond snail
Stagnicola catascopium catascopium (Say, 1817) lake stagnicola
Stagnicola catascopium nasoni (Baker, 1906) miniature lake-stagnicola
Stagnicola elodes (Say, 1821) common stagnicola
Stagnicola reflexa (Say, 1821) striped stagnicola
Superfamily Physacea
Family Physidae (tadpole snails)
Physa gyrina gyrina Say, 1821 tadpole snail
Physa integra Haldeman, 1841 solid lake physa
Aplexa hypnorum (Linnaeus, 1758) polished tadpole snail
Superfamily Planorbacea
Family Planorbidae (ramshorn snails)
Gyraulus circumstriatus (Tyron, 1866) flatly coiled gyraulus
Gyraulus deflectus (Say, 1824) irregular gyraulus
Gyraulus parvus (Say, 1817) modest gyraulus
Armiger crista (Linnaeus, 1758) tiny nautilus snail
Promenetus exacuous exacuous (Say, 1821) keeled promenetus
Planorbula armigera (Say, 1821) Say's toothed planorbid
Helisoma anceps anceps (Menke, 1830) two-ridged ramshorn
Helisoma campanulatum campanulatum (Say, 1821) bell-mouthed ramshorn
Helisoma pilsbryi infracarinatum Baker, 1932 great carinate ramshorn
Helisoma trivolvis trivolvis (Say, 1816) larger eastern ramshorn
Family Ancylidae (true freshwater limpets)
Laevapex fuscus (C.B. Adams, 1841) dusky lily-pad limpet
Ferrissia fragilis (Tyron, 1863) oval lake limpet
Ferrissia parallela (Haldeman, 1841) flat-sided lake limpet
Ferrissia rivularis (Say, 1817) sturdy river limpet

Species

Class Pelecypoda
Order Eulamellibranchia
Superfamily Unionacea
Family Unionidae (pearly mussels)
Subfamily Ambleminae (button shells and relatives)
Amblema plicata (Say, 1817) three-ridge
Fusconaia flava (Rafinesque, 1820) pig-toe
Quadrula quadrula (Rafinesque, 1820) maple-leaf
Quadrula pustulosa (Lea, 1831) warty-back
Cyclonaias tuberculata (Rafinesque, 1820) purple pimple-back
Elliptio dilatata (Rafinesque, 1820) spike, or lady-finger
Pleurobema coccineum (Conrad, 1836) false pig-toe

Subfamily Anodontinae (floater mussels)
Alasmidonta viridis (Rafinesque, 1820) brook wedge mussel
Alasmidonta marginata Say, 1819 ridged wedge-mussel
Lasmigona complanata (Barnes, 1823) white heel-splitter
Lasmigona compressa (Lea, 1829) brook lasmigona
Lasmigona costata (Rafinesque, 1820) fluted shell
Simpsoniconcha (=*Simpsonaias*) *ambigua* (Say, 1825) mudpuppy mussel
Anodontoides ferussacianus (Lea, 1834) cylindrical floater
Anodonta grandis grandis Say, 1829 common floater
Anodonta imbecilis Say, 1829 paper pond-shell
Strophitus undulatus (Say, 1817) squaw-foot

Subfamily Lampsilinae (lamp-mussels)
Ptychobranchus fasciolaris (Rafinesque, 1820) kidney shell
Obliquaria reflexa Rafinesque, 1820 three-horned warty-back
Truncilla donaciformis (Lea, 1828) fawn's-foot
Truncilla truncata Rafinesque, 1820 deer-toe
Proptera alata (Say, 1817) pink heel-splitter
Carunculina parva (Barnes, 1823) lilliput mussel
Obovaria subrotunda (Rafinesque, 1820) round hickory-nut
Obovaria olivaria (Rafinesque, 1820) olive hickory-nut
Leptodea fragilis (Rafinesque, 1820) fragile paper-shell
Actinonaias carinata (Barnes, 1823) mucket
Ligumia nasuta (Say, 1817) pointed sand-shell
Ligumia recta (Lamarck, 1819) black sand-shell
Lampsilis fasciola Rafinesque, 1820 wavy-rayed lamp-mussel
Lampsilis radiata siliquoidea (Barnes, 1823) fat mucket
Lampsilis ventricosa (Barnes, 1823) pocket-book
Villosa fabalis (Lea, 1831) bean villosa
Villosa iris (Lea, 1830) rainbow shell
Dysnomia torulosa rangiana (Lea, 1839) northern riffle shell
Dysnomia triquetra (Rafinesque, 1820) tricorn pearly mussel

Species
Superfamily Sphaeriacea
Family Corbiculidae (little basket clams)
Corbicula fluminea (Muller, 1774) Asiatic clam
Family Sphaeriidae (fingernail clams and pea clams)
Subfamily Sphaeriinae (fingernail clams)
Sphaerium corneum (Linnaeus, 1758) European fingernail clam
Sphaerium nitidum Clessin, 1876 Arctic-alpine fingernail clam
Sphaerium rhomboideum (Say, 1822) rhomboid fingernail clam
Sphaerium simile (Say, 1816) grooved fingernail clam
Sphaerium striatinum (Lamarck, 1818) striated fingernail clam
Sphaerium lacustre (Muller, 1774) lake fingernail clam
Sphaerium partumeium (Say, 1822) swamp fingernail clam
Sphaerium securis (Prime, 1851) pond fingernail clam
Sphaerium transversum (Say, 1829) long fingernail clam
Subfamily Pisidiinae (pea clams or pill clams)
Pisidium amnicum (Muller, 1774) greater European pea clam
Pisidium idahoense Roper, 1890 giant northern pea clam
Pisidium adamsi Prime, 1852 Adam's pea clam
Pisidium casertanum (Poli, 1795) ubiquitous pea clam
Pisidium compressum Prime, 1852 ridged-beak pea clam
Pisidium equilaterale Prime, 1852 round pea clam
Pisidium fallax Sterki, 1890 river pea clam
Pisidium ferrugineum Prime, 1852 rusty pea clam
Pisidium henslowanum (Sheppard, 1825) Henslow's pea clam
Pisidium lilljeborgi Clessin, 1886 Lilljeborg's pea clam
Pisidium milium Held, 1836 quadrangular pill clam
Pisidium nitidum Jenyns, 1832 shiny pea clam
Pisidium rotundatum Prime, 1852 fat pea clam
Pisidium subtruncatum Malm, 1855 short-ended pea clam
Pisidium variabile Prime, 1852 triangular pea clam
Pisidium ventricosum Prime, 1851 globular pea clam
Pisidium walkeri Sterki, 1895 Walker's pea clam
Pisidium conventus Clessin, 1877 Arctic-alpine pea clam
Pisidium punctatum Sterki, 1895 perforated pea clam

[a]Data sources: Goodrich and Van der Schalie (1932), Berry (1943), Stansbery (1960), Clarke (1981).

APPENDIX H

HABITAT PREFERENCE OF FRESHWATER MOLLUSCA OF LAKE ST. CLAIR COASTAL MARSHES AND NEARSHORE WATERS[a]

Species	Depth preference		Substrate preference				Comments
	Shallow (<2 m)	Deep (>2 m)	Mud	Sand	Gravel & rock	Plants	
GASTROPODA							
Campeloma decisum	x		x	x			Eutrophic
Viviparus georgianus	x		x			x	
Cipangopaludina chinensis	x		x				Eutrophic
Valvata perdepressa		x		x			
Valvata piscinalis						x	
Valvata sincera	x	x	x			x	
Valvata tricarinata	x					x	
Cincinnatia cincinnatiensis		x	x	x			
Probythinella lacustris	x	x	x	x		x	
Marstonia decepta	x				x	x	
Amnicola limosa	x				x	x	
Amnicola walkeri	x		x			x	
Somatogyrus subglobosus		x					Rare
Pomatiopsis lapidaria	x		x			x	
Bithynia tentaculata	x				x	x	
Pleurocera acuta	x		x	x			
Goniobasis livescens	x	x			x		
Fossaria decampi	x		x	x	x	x	
Fossaria exigua	x		x	x		x	
Fossaria modicella	x		x	x		x	
Fossaria parva	x		x			x	
Bakerilymnaea dalli	x		x	x		x	
Pseudosuccinea columella	x		x			x	
Acella haldemani	x	x				x	Rare
Bulimnea megasoma	x		x			x	
Lymnaea stagnalis	x		x	x	x	x	
Stagnicola c. catascopiu	x				x		
Stagnicola c. nasoni	x				x		
Stagnicola elodes	x		x			x	
Stagnicola reflexa	x		x			x	

APPENDIX H (CONTINUED)

Species	Depth preference Shallow (<2 m)	Depth preference Deep (>2 m)	Substrate preference Mud	Substrate preference Sand	Substrate preference Gravel & rock	Substrate preference Plants	Comments
Physa gyrina	x		x			x	Eutrophic
Physa integra	x		x	x	x	x	Eutrophic
Aplexa hypnorum	x		x			x	Rare
Gyraulus circumstriatus	x					x	
Gyraulus deflectus	x		x			x	Eutrophic
Gyraulus parvus	x		x			x	
Armiger crista	x		x			x	Eutrophic
Promenetus exacuous	x		x			x	
Planorbula armigera	x		x			x	
Helisoma anceps	x		x	x		x	
Helisoma campanulatum	x		x	x		x	
Helisoma pilsbryi	x		x	x		x	
Helisoma trivolvis	x		x			x	
Laevapex fuscus	x		x			x	
Ferrissia fragilis	x		x			x	
Ferrissia parallela	x		x			x	
Ferrissia rivularis	x	x			x		
PELECYPODA							
Amblema plicata		x	x	x	x		
Fusconaia flava	x	x	x	x		x	
Quadrula quadrula	x	x	x	x		x	
Quadrula pustulosa		x	x	x	x		
Cyclonaias tuberculata		x	x		x		
Elliptio dilatata	x		x	x	x		
Pleurobema coccineum	x		x	x		x	
Alasmidonta viridis	x	x	x	x	x		
Alasmidonta marginata	x				x		
Lasmigona complanata	x		x	x			
Lasmigona compressa	x		x	x	x		
Lasmigona costata	x		x	x	x		
Simpsoniconcha ambigua	x		x		x		
Anodontoides ferussacianus	x	x	x	x			
Anodonta grandis	x		x		x		
Anodonta imbecilis	x		x	x			
Strophitus undulatus	x	x		x			
Ptychobranchus fasciolaris	x	x		x	x		Rare
Obliquaria reflexa	x	x	x	x	x		
Truncilla donaciformis	x		x	x			
Truncilla truncata	x		x	x			
Proptera alata	x		x				
Carunculina parva	x		x				
Obovaria subrotunda	x		x				

APPENDIX H (CONCLUDED)

Species	Depth preference Shallow (<2 m)	Depth preference Deep (>2 m)	Substrate preference Mud	Substrate preference Sand	Substrate preference Gravel & rock	Substrate preference Plants	Comments
Leptodea fragilis	x		x	x	x		
Actinonaias carinata	x			x	x		Rare
Ligumia nasuta	x		x	x			
Ligumia recta	x			x	x		
Lampsilis fasciola	x	x		x	x		
Lampsilis radiata	x	x	x	x	x		
Lampsilis ventricosa	x		x	x	x		
Villosa fabalis	x					x	
Villosa iris		x		x	x		
Dysnomia torulosa	x						
Dysnomia triquetra	x			x	x		
Corbicula fluminea	x		x	x			
Sphaerium corneum		x	x				
Sphaerium nitidum		x	x	x	x		
Sphaerium rhomboideum	x		x			x	
Sphaerium simile	x		x	x		x	
Sphaerium striatinum		x					
Sphaerium lacustre	x	x	x	x			
Sphaerium partumeium	x		x			x	
Sphaerium securis	x		x			x	
Sphaerium transversum		x	x	x			
Pisidium amnicum		x	x	x	x		
Pisidium idahoense	x		x	x			
Pisidium adamsi	x	x	x				
Pisidium casertanum	x	x	x	x		x	
Pisidium compressum	x		x	x	x	x	
Pisidium equilaterale	x			x		x	
Pisidium fallax		x		x	x		
Pisidium ferrugineum	x		x	x		x	
Pisidium henslowanum		x	x				Rare
Pisidium lilljeborgi		x	x	x	x		
Pisidium milium	x		x			x	
Pisidium nitidum	x		x	x	x		
Pisidium rotundatum	x		x			x	
Pisidium subtruncatum	x		x	x	x	x	
Pisidium variabile	x		x			x	
Pisidium ventricosum	x		x			x	
Pisidium walkeri	x		x	x	x	x	
Pisidium conventus		x	x				
Pisidium punctatum			x			x	

[a]Data sources: Goodrich and Van der Schalie (1932), Berry (1943), Clarke (1981).

APPENDIX I

FISH KNOWN OR PRESUMED TO UTILIZE THE COASTAL WETLANDS OF THE ST. CLAIR RIVER AND LAKE ST. CLAIR[a]

Family and species	Abundance Pre-1900	Abundance 1980
Family Acipenseridae		
Acipenser fulvescens (sturgeon)	Common	Uncommon
Family Lepisosteidae (gars)		
Lepisosteus osseus (longnose gar)	Common	Common
Lepisosteus oculatus (spotted gar)	Uncommon	Uncommon
Family Ammidae (bowfins)		
Amia calva (bowfin)	Common	Common
Family Esocidae (pikes)		
Esox lucius (northern pike)	Abundant	Common
Esox masquinongy (muskellunge)	Common	Uncommon
Esox americanus (grass pickerel)	Common	Common
Family Umbridae (mudminnows)		
Umbra limi (central mudminnow)	Common	Common
Family Clupeidae (herrings)		
Dorosoma cepedianum (gizzard shad)	Uncommon	Common
Family Cyprinidae (minnows and carps)		
Cyprinus carpio (carp)	Uncommon	Common
Carassius aruatus (goldfish)	Uncommon	Uncommon
Notemigonus crysoleucas (golden shiner)	Common	Common
Notropis emiliae (pugnose minnow)	Rare	Rare
Notropis anogenus (pugnose shiner)	Rare	Rare
Notropis heterolepis (blacknose shiner)	Common	Common
Notropis heterodon (blackchin shiner)	Common	Common
Notropis hudsonius (spottail shiner)	Abundant	Abundant
Notropis atherinoides (emerald shiner)	Abundant	Abundant
Notropis stramineus (sand shiner)	Common	Common
Notropis volucellus (mimic shiner)	Common	Common
Pimephales notatus (bluntnose minnow)	Abundant	Abundant
Pimephales promelas (fathead minnow)	Abundant	Abundant

APPENDIX I (CONCLUDED)

Family and species	Abundance Pre-1900	1980
Family Catostomidea (suckers)		
Catostomus commersoni (white sucker)	Abundant	Abundant
Erimyzon sucetta (lake chubsucker)	Common	Common
Minytrema melanops (spotted sucker)	Common	Common
Family Ictaluridae (catfishes)		
Ictalurus punctatus (channel catfish)	Common	Common
Ictalurus melas (black bullhead)	Uncommon	Uncommon
Ictalurus nebulosus (brown bullhead)	Common	Common
Ictalurus natalis (yellow bullhead)	Common	Common
Noturus gyrinus (tadpole madtom)	Common	Common
Family Cyprinodontidae (killifishes)		
Fundulus diaphanus (banded killifish)	Common	Common
Family Centrarchidae (sunfishes)		
Ambloplites rupestris (rock bass)	Common	Common
Lepomis cyanellus (green sunfish)	Common	Common
Lepomis gibbosus (pumpkinseed)	Abundant	Abundant
Lepomis macrochirus (bluegill)	Common	Common
Micropterus dolomieui (smallmouth bass)	Common	Common
Micropterus salmoides (largemouth bass)	Common	Common
Pomoxis annularis (white crappie)	Uncommon	Uncommon
Pomoxis nigromaculatus (black crappie)	Common	Common
Family Percidae (perches)		
Etheostoma exile (Iowa darter)	Common	Common
Etheostoma nigrum (johnny darter)	Abundant	Abundant
Perca flavescens (yellow perch)	Abundant	Common
Percina caprodes (logperch)	Common	Common
Stizostedion vitreum (walleye)	Abundant	Common
Family Perichthyidae (basses)		
Morone chrysops (white bass)	Common	Common
Family Sciaenidae (drums)		
Aplodinotus grunniens (freshwater drum)	Common	Common
Family Gasterosteidae (sticklebacks)		
Culea inconstans (brook stickleback)	Common	Common
Family Cottidae (sculpins)		
Cottus bairdi (mottled sculpin)	Common	Common

[a]Data source: Herdendorf et al. (1981c).

APPENDIX J

AMPHIBIANS AND REPTILES OCCURRING IN THE COASTAL WETLANDS OF LAKE ST. CLAIR AND THE ST. CLAIR RIVER[a]

Species	Abundance status
Class Amphibia (amphibians)	
Order Caudata (salamanders)	
Necturus maculosus (mudpuppy)	Common
Notophthalmus viridescens (red-spotted newt)	Common
Ambystoma tigrinum (eastern tiger salamander)	Common
Ambystoma laterale (blue-spotted salamander)	Common
Ambystoma maculatum (spotted salamander)	Common
Plethodon cinereus (red-backed salamander)	Abundant
Hemidactylium scutatum (four-toed salamander)	Rare
Order Salientia (frogs and toads)	
Bufo americanus (American toad)	Abundant
Hyla crucifer (northern spring peeper)	Common
Hyla versicolor (gray treefrog)	Common
Pseudacris triseriata (western chorus frog)	Common
Acris crepitans blanchardi (Blanchard's cricket frog)	Common
Rana clamitans melanota (green frog)	Common
Rana catesbeiana (bullfrog)	Common
Rana pipiens (northern leopard frog)	Abundant
Rana palustris (pickerel frog)	Common
Rana sylvatica (wood frog)	Common
Class Reptilia (reptiles)	
Order Squamata (snakes and lizards)	
Natrix s. sipedon (northern water snake)	Abundant
Thamnophis s. sirtalis (eastern garter snake)	Abundant
Thamnophis butleri (Butler's garter snake)	Uncommon
Thamnophis sauritus septentrionalis (northern ribbon snake)	Abundant
Storeria o. occipitomaculata (northern red-bellied snake)	Uncommon
Storeria d. dekayi (northern brown snake)	Common
Storeria dekayi wrightorum (midland brown snake)	Common
Heterodon platyrhinos (eastern hognose snake)	Common
Diadophis punctatus edwardsi (northern ringneck snake)	Common
Opheodrys v. vernalis (eastern smooth green snake)	Common

Species	Abundance status
Coluber constrictor foxi (blue racer)	Common
Elaphe vulpina gloydi (eastern fox snake)	Rare
Elaphe o. obsoleta (black rat snake)	Rare
Lampropeltis t. triangulum (eastern milk snake)	Common
Sistrurus c. catenatus (eastern massasauga)	Uncommon
Order Testudines (turtles)	
Chelydra s. serpentina (snapping turtle)	Common
Clemmys guttata (spotted turtle)	Rare
Sternothaerus odoratus (stinkpot)	Common
Graptemys geographica (map turtle)	Common
Chrysemys picta marginata (midland painted turtle)	Abundant
Emydoidea blandingi (Blanding's turtle)	Common
Trionyx s. spiniferus (eastern spiny softshell)	Rare

[a]Data sources: Ruthven et al. (1928), Conant (1975), Behler and King (1979), Herdendorf et al. (1981c).

APPENDIX K

BIRDS OCCURRING IN THE VICINITY OF LAKE ST. CLAIR AND ST. CLAIR RIVER COASTAL WETLANDS[a]

Species	Residence status[b]
WATERFOWL	
Class Aves (birds)	
Order Anseriformes	
Family Anatidae (swans, geese, and ducks)	
Subfamily Anserinae (swans and geese)	
Tribe Cygnini	
Cygnus columbianus (tundra swan)	M
Cygnus olor (mute swan)	YR
Tribe Anserini	
Anser albifrons (white-fronted goose)	M
Branta canadensis (Canada goose)	YR
Chen caerulescens (snow goose)	M
Subfamily Anatinae (ducks)	
Tribe Cairinini	
Aix sponsa (wood duck)	BR
Tribe Anatini (dabbling ducks)	
Anas crecca (green-winged teal)	M
Anas rubripes (American black duck)	YR
Anas platyrhynchos (mallard)	YR
Anas acuta (northern pintail)	BR
Anas discors (blue-winged teal)	BR
Anas clypeata (northern shoveler)	M
Anas strepera (gadwall)	BR
Anas americana (American wigeon)	M
Tribe Aythyini (diving ducks)	
Aythya valisineria (canvasback)	W
Aythya americana (redhead)	BR
Aythya collaris (ring-necked duck)	M
Aythya marila (greater scaup)	W
Aythya affinis (lesser scaup)	BR
Tribe Mergini	
Clangula hyemalis (oldsquaw)	M
Bucephala clangula (common goldeneye)	W

Species	Residence status
Bucephala albeola (bufflehead)	W
Lophodytes cucullatus (hooded merganser)	M
Mergus merganser (common merganser)	M
Mergus serrator (red-breasted merganser)	M
Tribe Oxyurini	
Oxyura jamaicensis (ruddy duck)	BR
WATERBIRDS	
Order Podicipediformes	
Family Podicipedidae (grebes)	
Podiceps auritus (horned grebe)	M
Podilymbus podiceps (pied-billed grebe)	BR
Order Pelecaniformes	
Family Pelecanidae (pelicans)	
Pelecanus erythrorhynchos (white pelican)	M
Order Gruiformes	
Family Rallidae (rails, moorhens, and coots)	
Rallus elegans (king rail)	BR
Rallus limicola (Virginia rail)	BR
Porzana carolina (sora)	BR
Gallinula chloropus (common moorhen)	BR
Fulica americana (American coot)	BR
WADING BIRDS	
Order Ciconiiformes	
Family Ardeidae (herons)	
Botaurus lentiginosus (American bittern)	BR
Ixobrychus exilis (least bittern)	BR
Ardea herodias (great blue heron)	YR
Casmerodius albus (great egret)	BR
Bubulcus ibis (cattle egret)	BR
Butorides striatus (green-backed heron)	BR
Nyticorax nyticorax (black-crowned night-heron)	BR
SHOREBIRDS	
Order Charadriiformes	
Family Charadriidae (plovers)	
Charadrius semipalmatus (semipalmated plover)	M

Species	Residence status
Charadrius vociferous (killdeer)	BR
Pluvialis squatarola (black-bellied plover)	M
Family Scolopacidae (sandpipers)	
Tringa melanocleuca (greater yellowlegs)	M
Tringa flavipes (lesser yellowlegs)	M
Actitus macularia (spotted sandpiper)	BR
Bartramia longicauda (solitary sandpiper)	M
Calidris alba (sanderling)	M
Calidris minutilla (least sandpiper)	M
Calidris melanotos (pectoral sandpiper)	M
Calidris alpina (dunlin)	M
Limnodromus scolopaceus (long-billed dowitcher)	M
Arenaria interpres (ruddy turnstone)	M
Scolopax minor (American woodcock)	BR
Gallinago gallinago (common snipe)	BR
GULLS AND TERNS	
Order Charadriiformes	
Family Laridae (gulls and terns)	
Subfamily Larinae (gulls)	
Larus philadelphia (Bonaparte's gull)	W
Larus delawarensis (ring-billed gull)	YR
Larus hyperboreus (glaucous gull)	W
Larus argentatus (herring gull)	YR
Larus minutus (little gull)	YR
Larus marinus (great black-backed gull)	W
Larus glaucoides (Iceland gull)	W
Subfamily Sterinae (terns)	
Sterna caspia (Caspian tern)	BR
Sterna hirundo (common tern)	BR
Sterna forsteri (Forster's tern)	BR
Chlidonias niger (black tern)	BR
RAPTORS	
Order Falconiformes	
Family Accipitridae (ospreys)	
Pandion haliaetus (osprey)	BR

Species	Residence status
Family Accipitridae (hawks, eagles)	
Subfamily Accipitrinae	
Haliaeetus leucocephalus (bald eagle)	YR
Circus cyaneus (northern harrier)	YR
Accipiter striatus (sharp-shinned hawk)	YR
Accipiter cooperii (Cooper's hawk)	YR
Aquila chrysaetos (golden eagle)	M
Buteo jamaicensis (red-tailed hawk)	YR
Buteo lagopus (rough-legged hawk)	W
Buteo platypterus (broad-winged hawk)	BR
Family Falconidae (falcons)	
Falco sparverius (American kestrel)	YR
Order Strigiformes	
Family Strigidae (owls)	
Asio flammeus (short-eared owl)	YR
PERCHING AND OTHER BIRDS	
Order Coraciiformes	
Family Alcedinidae (kingfishers)	
Ceryle alcyon (belted kingfisher)	YR
Order Passeriformes	
Family Troglodytidae (wrens)	
Cistothorus palustris (marsh wren)	BR
Cistothorus platensis (sedge wren)	BR
Family Muscicapidae (thrushes)	
Catharus fuscescens (veery)	BR
Family Emberizidae	
Subfamily Parulinae (wood warblers)	
Dendroica petechia (yellow warbler)	BR
Geothlypis trichas (common yellowthroat)	BR
Subfamily Icterinae	
Sturnella magna (eastern meadowlark)	YR
Xanthocephalus xanthocephalus (yellow-headed blackbird)	BR
Agelaius phoeniceus (red-winged blackbird)	YR
Quiscalus quiscula (common grackle)	YR

APPENDIX K (CONCLUDED)

Species	Residence status
Subfamily Emberizinae (sparrows)	
Melospiza georgiana (swamp sparrow)	YR
Passerculus sandwichensis (savannah sparrow)	BR

[a]Data sources: Peterson (1980), Herdendorf et al. (1981c), Scott (1983).

[b]Residence key:
YR - Year-round resident   BR - Breeding range (spring and summer)
M - Migrant   W - Winter range

APPENDIX L

MAMMALS OCCURRING IN THE COASTAL WETLANDS OF LAKE ST. CLAIR AND THE ST. CLAIR DELTA[a]

Species	Abundance status
Order Marsupialia (marsupials)	
Family Didelphidae	
Didelphis virginiana (Virginia opossum)	Common
Order Lagomorpha	
Family Leporidae	
Sylvilagus floridanus (eastern cottontail)	Common
Lepus capensis (=*europaeus*) (European hare)	Rare
Order Rodentia	
Family Sciuridae	
Marmota monax (woodchuck)	Occasional
Sciurus carolinensis (gray squirrel)	Uncommon
Sciurus niger (fox squirrel)	Uncommon
Tamiasciurus hudsonicus (red squirrel)	Occasional
Family Cricetidae	
Ondatra zibethicus (muskrat)	Abundant
Order Carnivora	
Family Canidae	
Vulpes fulva (red fox)	Occasional
Family Procyonidae	
Procyon lotor (raccoon)	Occasional
Family Mustelidae	
Mustela frenata (long-tailed weasel)	Occasional
Mustela vison (mink)	Occasional
Mephitis mephitis (striped skunk)	Common
Taxidea taxus (badger)	Rare
Order Artiodactyla	
Family Cervidae	
Odocoileus virginianus (white-tailed deer)	Occasional

[a]Data sources: Hayes (1964), Herdendorf et al. (1981c).

APPENDIX M

OWNERSHIP OF MAJOR LAKE ST. CLAIR WETLANDS

Wetland Name	Ownership[a] Public	Ownership[a] Private	Relative area[b]	Water-level control[c]	Veg. type[d]
WAYNE COUNTY, MICHIGAN					
1. Belle Isle	M/F	-	M	U	S
MACOMB COUNTY, MICHIGAN					
2. Black Creek	-	PM	S	U	E
3. Clinton River Estuary	M	PM	S	U	E/S
4. Belvidere Bay	-	PS	S	U	S/E
5. Salt River Estuary	-	PM	M	U	E
ST. CLAIR COUNTY, MICHIGAN					
6. Marsac Point	-	PM	M	U	E/S
7. Swan Creek Estuary	-	PM	M	U/D	E
8. St. John's Marsh	S	PM	M	U	E
9. Dickinson Island	S/F	PM	L	U	E/S
10. Harsens Island	S	PM	L	D/U	E/S
11. Belle River Estuary	-	PM	S	U	E
12. Pine River Estuary	M	PM	S	U	E
13. Marysville	-	PS	S	U	E
14. Port Huron	-	PM	S	U	E
ESSEX COUNTY, ONTARIO					
15. Peach Island	M	-	S	U	S
16. Ruscom River	-	PM	S	U	E/S
17. Thames River Estuary	M	PM/SC	M	D/U	E
KENT COUNTY, ONTARIO[e]					
18. Bradley Marsh	S	PS	M	D	E
19. Big Point Marsh	F	SC	M	S/U	E/S
20. Tacky Marsh	-	PM/SC	M	D/U	E/S
21. Mitchell Point Marsh (Moon Island Marsh)	-	SC	M	D/U	E
22. Mitchell Bay (Pintail and Mud Creek marshes)	S	PM/SC	L	D/U	E/S
23. Wallaceburg (Bear Creek and Pigeon marshes)	-	PM	L	D/U	E

APPENDIX M (CONCLUDED)

Wetland Name	Ownership Public	Ownership Private	Relative area	Water-level control	Veg. type
LAMBTON COUNTY, ONTARIO					
24. St. Anne Island	-	PM,R	L	D/U	E/S
25. Walpole Island	-	R	L	D/U	E/S
26. Squirrel Island	-	R	M	U	E
27. Bassett Island	-	R	L	U	E
28. Seaway Island	-	R	S	U	E
29. Port Lambton	-	PM	M	U	E/S
30. Fawn Island	-	PM	S	U	S
31. Stag Island	-	PM	S	U	S
32. Sarnia	M	PM	S	U	E

[a]Ownership Key:
F = Federal
S = State or Provincial
M = Municipal
SC = Shooting Club
PM = Private, multiple owners
PS = Private, single owner
R = Indian Reservation

[b]Area Key:
S = Small (>500 ha)
M = Medium (500-1,000 ha)
L = Large (>1,000 ha)

[c]Water-level Control Key:
D = Diked, managed marsh
U = Uncontrolled wetland

[d]Veg. Type Key:
S = Submergent
E = Emergent

[e]Note: Between Bradley Marsh (18) and Mitchell Bay (22) several shooting clubs operate small marshes, including Recess Club, Balmoral Club, St. Lukes Club, Rex Club, Bay Loge Club, Rex/Cadotte Marsh, and Rankin/Sloan Marsh.

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16. Abstract (Limit: 200 words)

This publication reviews the ecological data and information on the wetlands of Lake St. Clair. The lake, which is a part of the Great Lakes ecosystem, is situated between southeastern Michigan and southwestern Ontario. Lake St. Clair contains a substantial portion of the remaining Great Lakes coastal wetlands, with extensive wetlands occurring in the vicinity of the St. Clair River Delta. These wetlands are among the most productive areas in the Great Lakes ecosystem. This publication summarizes the geologic history of the region leading to the development of wetlands and the present environment; biological production and community organization in the Lake St. Clair wetlands are also examined. The publication closes with a chapter on applied ecology which addresses issues such as wetland disturbance, management, and future prospects for these wetlands.

17. Document Analysis a. Descriptors

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Delta
Fish
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b. Identifiers/Open-Ended Terms

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